



Ontario Geological Survey
Open File Report 6020

**Nature, Timing and
Significance of Intermediate
to Felsic Intrusive Rocks
Associated with the Hemlo
Greenstone Belt and
Implications for the
Regional Geological Setting
of the Hemlo Gold Deposit**

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ONTARIO GEOLOGICAL SURVEY

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Nature, Timing and Significance of Intermediate to Felsic Intrusive Rocks Associated with the Hemlo Greenstone Belt and Implications for the Regional Geological Setting of the Hemlo Gold Deposit

by

G.P. Beakhouse

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associated with the Hemlo Greenstone Belt and Implications for the Regional
Geological Setting of the Hemlo Gold Deposit**

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Introduction

The Hemlo greenstone belt lies within the Wawa subprovince of the Superior Province. The greenstone belt is bounded to the north, south and east by large granitoid batholiths. The western limit of the greenstone belt, and possible continuity with the Terrace Bay-Schrieber greenstone belt, is obscured by the Proterozoic Coldwell alkalic intrusion and the waters of Lake Superior. The greenstone belt is also intruded by several relatively large plutons as well as numerous minor intrusions and abundant dikes that are internal to the greenstone belt.

The generalized distribution of units is based largely on detailed and semi-detailed regional mapping (Milne, 1968, Muir, 1982a,b and Siragusa, 1984a,b, 1985a,b). Additionally, many detailed investigations have focused on geological relationships in the immediate area of the Hemlo gold deposit (Muir, 1997 and references cited therein). The economic significance of the Hemlo gold deposit, together with the wealth of controversy generated by the detailed studies, led to the formulation of a Canadian Mining Industry Research Organization (CAMIRO) project focusing on the deposit. The Ontario Geological Survey undertook regional thematic investigations of the supracrustal rocks (S.L. Jackson) and intrusive rocks (this study) to build on the previously established geological framework and compliment the CAMIRO investigation. Preliminary geochronological data reported here are from ongoing work carried out in conjunction with D.W. Davis (Royal Ontario Museum).

Intermediate to felsic intrusive rocks associated with the Hemlo greenstone belt are considered on the basis of their field and temporal relationships together with textural, mineralogical and geochemical characteristics. On this basis, individual units are distinguished and characterized, and interpretations of the petrogenesis of the units and their significance for the development of the greenstone belt and its contained mineral deposits are developed.

Distribution of Intermediate to Felsic Intrusive Rocks

Intermediate to felsic intrusive rocks were distinguished in the field on the basis of their fabric and mineralogical composition as well as relationship to country rock and regional deformational fabrics. This distinction is augmented by petrographic, geochemical and geochronological data summarized in subsequent parts of this report. The distribution of regionally mappable units and many of the discrete minor intrusions is illustrated in Figure 1 and the general characteristics leading to the initial distinction of units is summarized in Table 1. The three dimensional geometry, interpreted from compiled and new observations, is shown in Figure 2.

Table 1. General field characteristics leading to the initial distinction of intermediate to felsic intrusive units identified within and near the Hemlo greenstone belt.
Abbreviations; hbl- hornblende, bt- biotite, plag- plagioclase.

Unit	Type	Distinguishing Characteristics	Additional Comments
Black – Pic Batholith	bounding batholith	predominant foliated to gneissic tonalite to granodiorite with local massive to foliated phases and abundant, diverse minor phases	investigated in reconnaissance fashion only
Pukaskwa Batholith	bounding batholith	predominant foliated to gneissic tonalite to granodiorite with abundant, diverse minor phases	investigated in reconnaissance fashion only
Cedar Lake pluton	internal pluton	massive to weakly foliated hbl granodiorite; more magnetic variety locally near margin; widespread, minor dioritic phases	fabric generally parallel to pluton margins mutually intrusive relationships indicate the granodioritic and dioritic phases represent coeval, compositionally distinct magmas
Heron Bay pluton	internal pluton	massive hbl-bt granodiorite with equigranular, microcline-megacrystic and plag subporphyritic textural varieties	cross-cuts regional D ₁ fabric; a narrow septa of metavolcanic /metasedimentary rock separates the northeastern part from the main mass of the pluton
Gowan Lake pluton	external, bounding pluton	massive to foliated, texturally and mineralogically heterogeneous, magnetic, hbl-bt quartz monzodiorite; widely distributed, moderately abundant dioritic to monzonitic enclaves	distinctive acicular hbl; wide variation in color index; foliation is locally interpreted to be a primary magmatic flowage feature
Dotted Lake pluton	external, bounding pluton	massive to foliated, compositionally homogeneous, bt leucogranodiorite to leucotonalite; very few enclaves or inclusions	most of pluton is massive to weakly foliated/lineated; strong, tectonic foliation at margin of pluton parallel to that in the country rock; shear zones locally in interior occurs within the Black – Pic batholith
Fourbay Lake pluton	external pluton	massive, magnetic, hbl-bt quartz monzodiorite	
Musher Lake pluton	internal pluton	massive, hbl-bt tonalite; irregular, sill-like geometry but poorly exposed	cross-cuts folded D ₁ regional fabric
Cedar Creek stock	internal pluton	massive, magnetic hbl-bt granodiorite; very rare dioritic enclaves	
Satellite stock	internal pluton	massive, magnetic hbl-bt granodiorite	poorly exposed
Melgund stock	internal pluton	massive, hbl-bt tonalite	
Ogilvie Island pluton	internal pluton	massive, bt granodiorite	extent concealed beneath waters of Lake Superior
Picture Island stock	internal pluton	massive, bt granodiorite	Locally transected by shears and mylonitic fabrics
White River pluton	internal pluton	massive, hbl monzodiorite to quartz monzodiorite; sill-like body	poorly exposed; limited data suggests north side is more mafic and may be a differentiated sill
Botham stock	internal pluton	two phases; foliated, equigranular bt granodiorite and a finer grained, well foliated feldspar porphyry	the two phases may be genetically and temporally distinct
Moose Lake porphyry	volcanic to sub-volcanic	Highly altered and deformed, fine grained, quartz porphyritic unit; includes massive and fragmental varieties with the latter locally being layered	Fragmentation mechanisms may include synvolcanic and later hydrothermal brecciation in addition to primary fragmentation

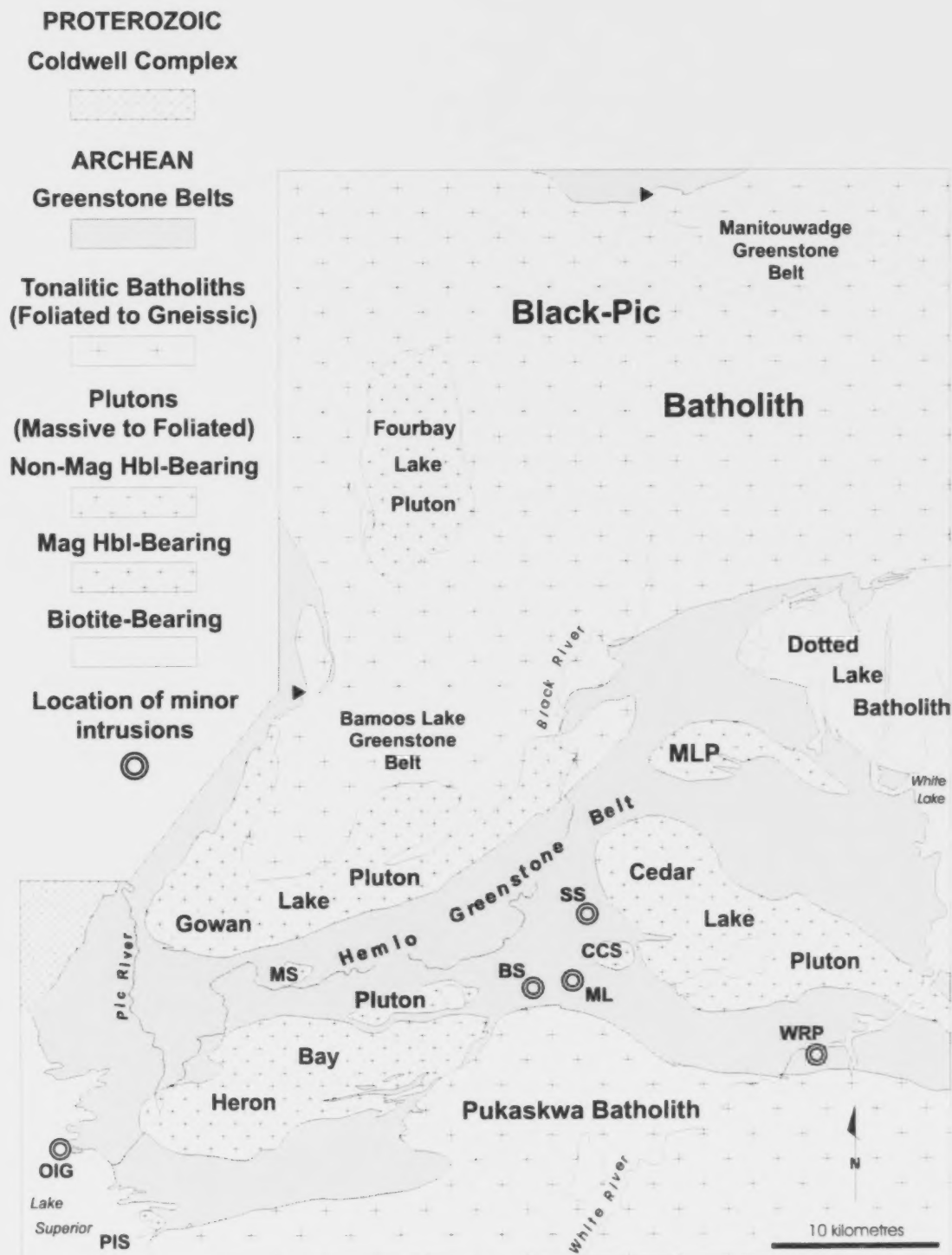


Figure 1. Generalized geology of the Hemlo greenstone belt illustrating the location of intrusive rocks discussed in the text. Abbreviations are as follows; BS = Botham stock, CCS = Cedar Creek stock, ML = Moose Lake porphyry, MLP = Musher Lake pluton, MS = Melgund stock, OIG = Ogilvie Island granodiorite, PIS = Picture Island stock, SS = Satellite stock, WRP = White River pluton

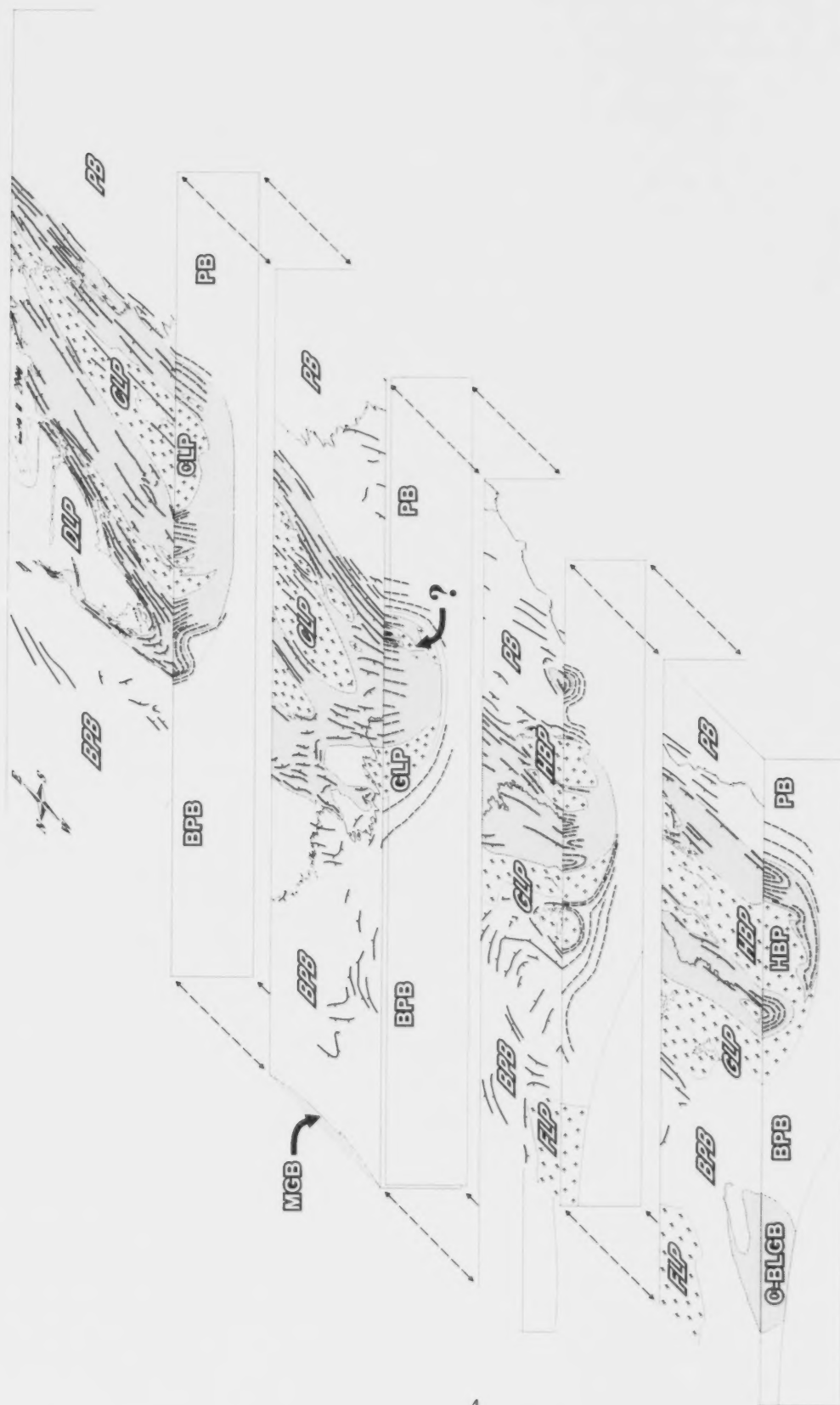


Figure 2. Block diagram illustrating the interpreted geometric configuration of the greenstone belt and plutons. The sectional views incorporate downplunge projections of features located off the section line. The portrayal of granitoid rock beneath the Hemlo gold deposit (indicated by the question mark) is hypothetical and is merely intended to indicate the possible existence of unexposed plutons at depth.

A broad compositional spectrum of small, dike-like to irregular intrusions, that are too small to display on regional geological maps, are widely distributed within the greenstone belt. Varieties considered here include earlier, deformed, felsic, quartz $\pm$ feldspar porphyries and later, less deformed, intermediate to felsic dikes. These types of minor intrusions are abundant in the vicinity of the Hemlo gold deposit and occur locally elsewhere in the greenstone belt (e.g., in a highly deformed heterolithic lithotectonic unit immediately north of the Musher Lake pluton). Understanding of the distribution of these rocks in many areas is influenced by the quality and abundance of bedrock exposures but there appear to be at least some areas (e.g., mafic dominated sequences on the north and south flanks of the greenstone belt) where these intrusions are absent or very much less abundant.

Fine to very coarse grained, granitic, aplitic to pegmatitic dikes are a conspicuous feature within the large bounding batholiths and also occur locally within the greenstone belt. In general, with the exception of the Black-Pic and Pukaskwa batholiths, these dikes exhibit a close spatial association with major greenstone – granitoid contacts: the pegmatitic-aplitic rocks may be genetically related to these larger granitoid masses or their distribution may be localized in zones of dilatancy associated with heterogeneous strain along granite greenstone contacts.

Field Relationships and Timing of Intermediate to Felsic Intrusive Rocks

This section describes general field relationships of the units investigated in this study. This includes the both the relationship with country rocks and deformational fabrics therein, as well as relationships between the various components of the intrusions themselves. For the purposes of this discussion, the sequence of regional deformational events is considered to consist of an earlier fabric-forming event(s) referred to as D_1 and subsequent deformational event(s) (D_2) that deform the earlier fabric (Jackson, 1998). Fabrics related to the D_2 deformation locally overprint D_1 fabrics. The various stages of the more complex sequence of deformational events deduced for the Hemlo deposit area (Muir, 1997) cannot at this stage be unambiguously related to the regional deformational history. Unless otherwise noted, all subsequent discussion of D_1 and D_2 deformation refers to the regional deformational sequence. This discussion also incorporates the results of previously published geochronological investigations (Corfu and Muir, 1989a, 1989b) as well as new high-precision U-Pb age determinations carried out as part of this investigation in collaboration with D.W. Davis (Davis et al., 1998).

Belt-Bounding Batholithic Complexes

The Pukaskwa batholith is in direct contact with the Hemlo greenstone belt to the south and the Black-Pic batholith lies to the north and east of the greenstone belt. Along much of the northern and eastern contact, the Black-Pic batholith and the greenstone belt are separated by intervening massive to foliated plutons (Dotted Lake batholith, Gowan Lake pluton). Both the Pukaskwa and Black-Pic batholiths are parts of poorly understood granitoid terranes that cover thousands of square kilometres, only parts of which have

been investigated in reconnaissance fashion. The Pukaskwa batholith is similar in many respects to the Black-Pic batholith and, viewed on a larger scale, may be continuous with one another around the eastern end of the Hemlo greenstone belt. The principal difference is that large areas of a massive to foliated component were not encountered in the Pukaskwa batholith although this may reflect the limited mapping of this large batholith. Additional minor differences include a greater abundance of entrained amphibolite in the Black-Pic batholith and greater diversity of minor late intrusive phases in the Black-Pic batholith. For the purpose of this report, the Pukaskwa and Black-Pic batholiths are considered to be belt-bounding batholithic complexes and are discussed together.

The belt-bounding batholiths are comprised of a predominant, heterolithic, gneissic suite along with regionally subordinate, locally dominant, massive to foliated diorite to quartz monzodiorite, minor massive to foliated granodiorite and minor, widely distributed, compositionally and texturally diverse late intrusive phases.

The gneissic assemblage is moderately to extremely heterolithic on an outcrop scale, being comprised of three principal components; amphibolite, gneissic tonalite-granodiorite and late intrusive phases. The oldest component on the basis of field relationships is locally abundant amphibolite forming lenticular/tabular units intruded by tonalite-granodiorite (Plate 1). The amphibolite has a general basaltic composition and a mineral assemblage (hornblende + plagioclase $\pm$ clinopyroxene $\pm$ garnet) indicative of upper amphibolite facies metamorphic conditions. A significant proportion of the amphibolite component is interpreted to be of mafic volcanic origin on the basis of local, highly deformed and disrupted compositional heterogeneity interpreted to reflect original pillow selvages as well as local, regularly distributed calc-silicate mineralogy interpreted to reflect metamorphosed sea-water alteration.

Biotite $\pm$ hornblende tonalite to granodiorite intrudes the amphibolite component and both are strongly deformed and recrystallized resulting in the formation of ubiquitous, well-developed mineral foliations/lineations and variously developed compositional layering. In addition to compositional layering introduced by intense flattening and transposition of the entrained amphibolite component, compositional layering in the tonalite-granodiorite includes thin (2-10 mm) lenses of more leucocratic tonalite-granodiorite with narrow mafic-mineral enriched selvages that may represent incipient partial melting. Alternatively, this type of layering may be due to metamorphic differentiation, involving a fluid but not necessarily a magmatic component. In either case, this type of layering is also interpreted to have developed under elevated temperature and pressure conditions consistent with those inferred from the mineral assemblage in the amphibolite. Preliminary U-Pb zircon geochronological data for a gneissic tonalite from the Black-Pic batholith indicates magmatic zircons ca. 2720 Ma and metamorphic zircons as young as 2688 Ma (Table 2). A preliminary U-Pb zircon age of approximately 2718 Ma was obtained for a tonalite from the Pukaskwa batholith within meters of the greenstone belt contact on Lake Superior. These ages are closely comparable to ages reported previously for the Pukaskwa batholith (2719^{+6}_{-4} Ma, Corfu

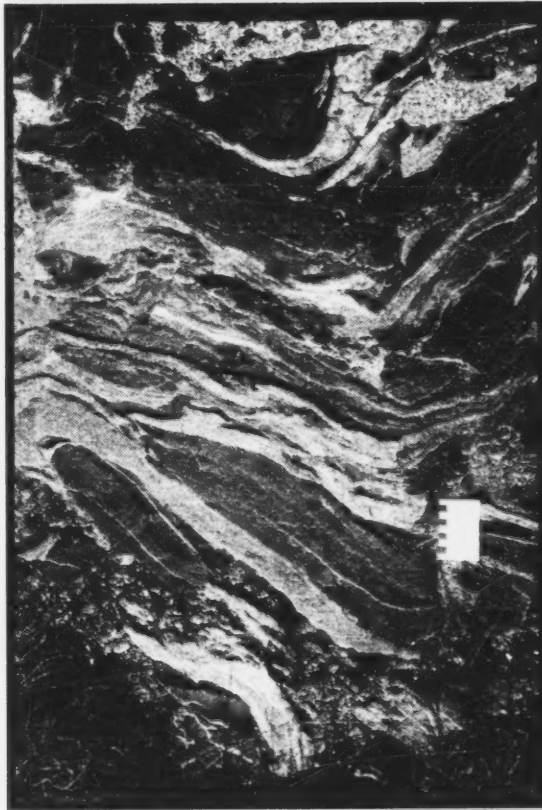


Plate 1. Outcrop photos illustrating typical relationship between the amphibolite and gneissic tonalite components of the Black-Pic batholith. Photo "a" illustrates sheet-like tonalite intruding amphibolite. Intense flattening and transposition of amphibolite and tonalite along with granitic, pegmatoid sheets (photo "b") results in formation of well developed, planar compositional layering. Amphibolite blocks are commonly rotated during development of deformational fabrics leading to local discordance (photo "c")

Table 2. Summary of geochronological and isotopic results for intermediate to felsic intrusive rocks associated with the Hemlo greenstone belt.

Unit	U-Pb Zircon			U-Pb Sphene	ϵ_{Nd}^1	Comments	Ref
	Inheritance	Magmatic	Cooling				
Earlier (Pre D₁) Igneous Rocks							
Black-Pic Batholith		~2720	~2688,~2693, ~2701		+2.9	Gneissic unit	1
Pukaskwa Batholith		2719 ⁺⁶ ₋₄ 2718			+3.0 - +3.3	Heterogeneous, foliated unit	2 1
Dotted Lake Batholith		2697 ± 1			+2.3		1
Moose Lake Porphyry	~2700,~2720, ~2762,~2796	2772 ± 2 ?			+2.9	Age problematic due to inheritance	2,5
Later (Syn- to Late-D₂) Plutonic Group							
Pukaskwa Batholith	~2732	2688 ± 3				Weakly Foliated granodiorite	2
Black-Pic Batholith		2687 ⁺³ ₋₂				Foliated Diorite	4
Cedar Lake Pluton		2688 ± 3			+1.8 - +3.1	Main granodiorite phase	2
Cedar Lake Pluton		2687 ± 3			+2.6	Marginal magnetic granodiorite phase	2
Cedar Lake Pluton				2675 ± 5	+1.9 - +2.3	Diorite phase – no good zircon recovered	
Heron Bay pluton	~2703	2688 ± 5			+1.9 - +2.7	low zircon yield -fractions used from 2 samples	2
Heron Bay pluton (East)		~2690	~2677			Plag subporphyritic phase cross-cutting D ₁ fabric	1
Heron Bay pluton (West)	~2724	~2690	~2681			Equigranular granodiorite phase	1
Feldspar Porph Dike	~2690,~2699	2687 ± 3			+2.3		2
Cedar Creek stock	~2692	2684 ⁺⁴ ₋₃			+2.1	Main granodiorite phase	2
Botham stock		~2689		2672 ± 23	+2.0	Medium grained phase	1
Musher Lake pluton		~2679			+2.4	Main phase containing inclusions with folded D1 fabric	1
Fourbay Lake pluton		~2678			+2.4		1
Gowan Lake pluton		2678 ± 2			+1.7 - +2.0		2

References: 1- Davis et al., this volume, 2- Corfu and Muir (1989a), 3- Corfu and Muir (1989b), 4- Zaleski et al.(1995), 5- Wasteneys (1995) as reported in Johnston (1996)

and Muir, 1989a) although it is not clear how the sample dated by these authors relates to the history described here.

The layered nature of these rocks is also accentuated by the tabular form of variously deformed younger intrusive phases (Plate 2). Granitic phases predominate but these younger intrusive phases range from dioritic to granitic in composition. In some cases, these units appear to have been emplaced as concordant sheets parallel to a pre-existing anisotropy in the tonalite-amphibolite assemblage. In other cases, these younger intrusive phases are dikes discordant to a pre-existing anisotropy that have been transposed into near parallelism with the other layering in the rock by intense deformation. In many outcrops there appears to be a continuum from strongly deformed transposed dikes to undeformed dikes suggesting that this magmatic phase was in part synchronous with, but outlasted, regional deformation.

Observations and interpretations discussed above indicate that the layered gneissic character of the gneissic assemblage is composite and reflects a range of intrusive, deformational and metamorphic processes. Future geochronological investigations may further constrain the timing of development of the gneissic fabric.

The proportion of amphibolite, tonalite and granite within the gneissic units of the Black-Pic batholith varies widely but tends to be consistent along strike and vary abruptly across strike. This lithologic variability imparts a gneissic 'stratigraphy' to this component of the batholith that, along with the planar tectonic fabrics, is deformed into regional scale domical structures that are characterized by horizontal to shallow dips in the central portion and steeper dips towards their margins. Some of the transposition of discordant intrusive phases may be related to this phase of the regional deformational history. In the Mussey Lake area, southeast of the Heron Bay pluton, a strong penetrative fabric in the Pukaskwa batholith is parallel to that in the greenstone belt and both are deformed in a regional scale fold (Jackson, 1998). On this basis, regional folding of the gneissic 'stratigraphy' is interpreted to be related to the regional folding of the greenstone belt.

More homogeneous, massive to foliated igneous rocks predominate locally. In the central and northern portions of the Black-Pic batholith, dioritic to quartz monzodioritic intrusive rocks are abundant. Zaleski et al. (1995) report an age of 2687^{+3}_{-2} Ma for a foliated diorite from the Black-Pic batholith immediately south of the Manitouwadge greenstone belt. These rocks may be correlative with some of the weakly deformed, younger, minor intrusive phases that intrude the older tonalitic and amphibolitic components of the gneissic assemblage. Massive to foliated granodiorite is locally abundant within the bulbous northward projection of the Pukaskwa batholith located east of the Heron Bay pluton (Figure 1). A weakly foliated granodiorite from the Pukaskwa batholith has an inferred magmatic crystallization age of 2688 ± 3 Ma and contains an older xenocrystic component at least as old as 2732 Ma (Corfu and Muir, 1989a). The U-Pb ages for foliated to massive phases of the Black-Pic and Pukaskwa batholiths are comparable to those for many of the discrete massive to foliated plutons discussed in a subsequent section (Table 2).

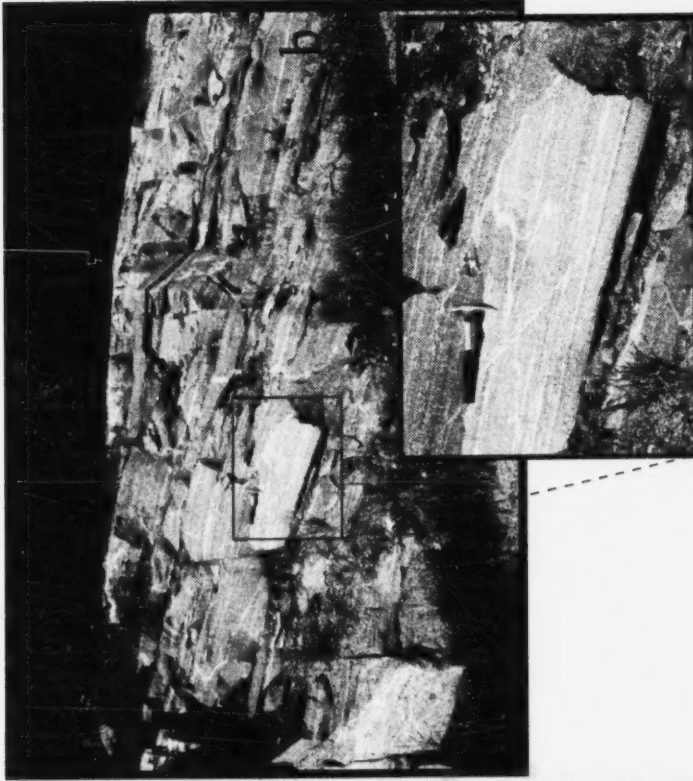
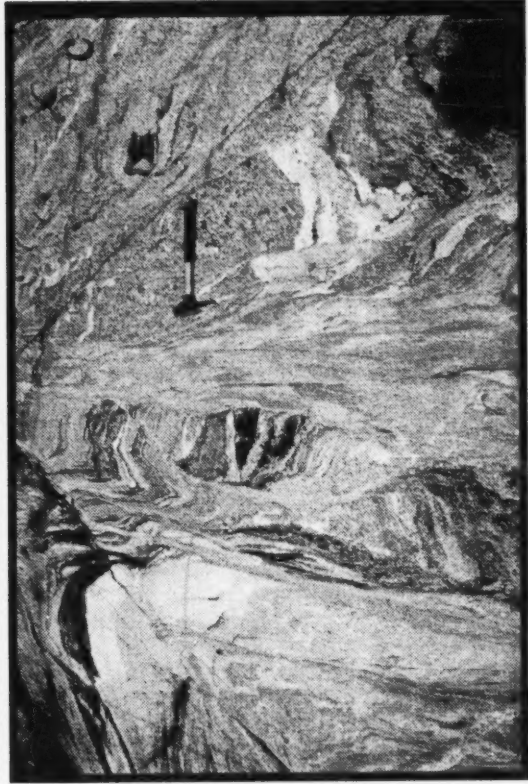


Plate 2. Outcrop photos illustrating the nature of deformation induced layering within heterogeneous gneissic rocks.

- Photo "a" illustrates subhorizontal layered amphibolite - tonalite with deformed discordant leucogranitic sheet (Black-Pic Batholith).
- Photo "b" with inset illustrates variously deformed leucogranitic to leucotonalitic sheets that where tightly buckled or transposed enhance pre-existing gneissic layering (Black-Pic Batholith).
- Photo "c" illustrates formation of a second gneissic fabric by intense transposition of an earlier gneissic fabric (Pukaskwa Batholith)

There are also several other noteworthy minor, but widespread, intrusive rock types. Mafic and lamprophyric phases are widespread minor components in the Black-Pic batholith and although many of these are very late (perhaps even Proterozoic), some have been moderately deformed and are intruded by late pegmatoid veins and dikes. Some of the mafic (dioritic to gabbroic) dikes are characterized by distinctive acicular amphiboles and on this basis may have affinities to an appinite suite. Distinctive, heterogeneous intrusion breccias with dioritic matrix occur locally in the Black-Pic batholith and are generally undeformed (Plate 3). Fine grained, intermediate feldspar porphyry occurs as dikes in the Pukaskwa batholith to the east of the Heron Bay pluton. Contact relationships between the Black-Pic batholith and Hemlo greenstone belt are either poorly exposed or obscured by intervening younger plutons. The vicinity of the contact between the Hemlo greenstone belt and the Pukaskwa batholith is reasonably well exposed and generally not obscured by emplacement of intervening younger intrusive rocks. The contact is very sharp and associated with very high strain, which appears to decrease southwards into the interior of the batholith. Mylonitic fabrics are developed locally in the tonalite of the Pukaskwa batholith as well as in the Picture Island pluton described below. Current broad constraints on the timing of fabric development are consistent with the hypothesis that the gneissic fabrics in the bounding batholiths have been folded along with the regional D_1 fabric within the Hemlo greenstone belt. Although many of the late intrusive phases intrude both the batholiths and greenstone belt in the vicinity of their contacts, there are no unambiguous examples of gneissic tonalite intruding, or containing inclusions of, the Hemlo greenstone belt. Consequently, the contact between the greenstone belt and bounding batholiths could represent either a tectonic contact or an unconformity or sharp intrusive contact with superimposed high strain.

Massive to Foliated Plutons

Discrete, massive to foliated plutons generally have distinct, sharp, intrusive contacts with the greenstone belt and/or gneissic assemblage that they intrude. In some cases the plutons lie wholly within the greenstone belt (Cedar Lake, Heron Bay, Cedar Creek, Musher Lake, Melgund plutons among others; Figure 1). The Fourbay Lake pluton lies entirely within the BPB. Others (Gowan Lake pluton, Dotted Lake batholith; Figure 1) occur along the interface between the greenstone belt and bounding batholiths. The characteristics and internal and contact relationships of some of these plutons are summarized below.

Cedar Lake Pluton

The Cedar Lake pluton is internal to the greenstone belt and comprised of predominant granodiorite together with widely distributed, minor diorite to quartz monzodiorite enclaves/dikes and ultramafic clots and minor granitic pegmatite/aplite. The granodiorite can be further subdivided into a non-magnetic and minor, areally restricted magnetic variety.

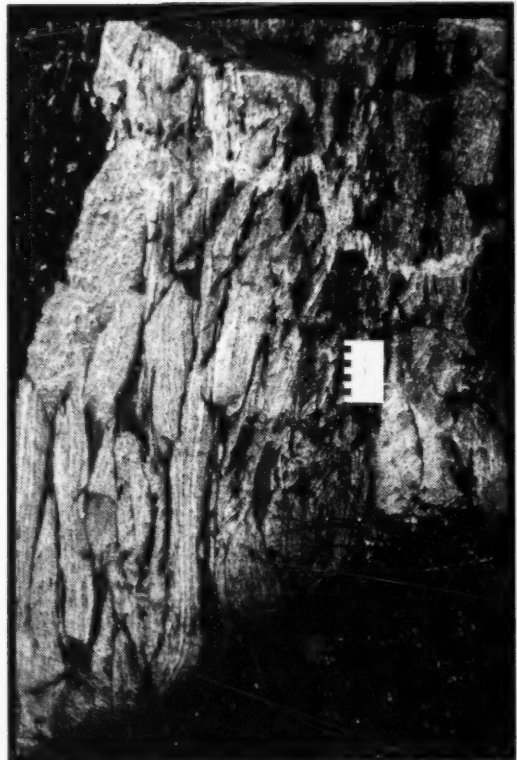
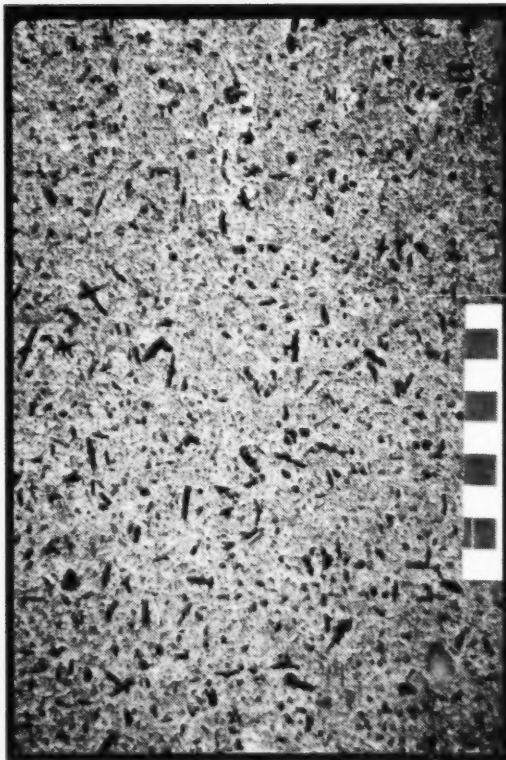


Plate 3. Minor intrusion types occurring in the Black-Pic Batholith.

- Photo "a". Possible appinite suite dike with distinctive acicular amphibole.
- Photo "b". Intrusion breccia with dioritic matrix.
- Photo "c". Tectonic/intrusion breccia with lamprophyre filling the interstices between fragments.

The non-magnetic variety of granodiorite greatly predominates over all of the other phases of the pluton, constituting >95% of all but two outcrops examined. The magnetic granodiorite predominates in the two exceptions; both of these outcrops occur along the southwestern contact of the pluton.

The diorite to quartz monzodiorite phase occurs in a range of associations with the granodiorite (Plate 4). The most common association, occurring in virtually every outcrop, is as disc-shaped enclaves that are widely distributed and typically constitute <2% of the outcrop. The longest dimension of the enclaves is typically 5-20 cm but ranges from a few centimetres to metre sized bodies. The margins of the enclaves may be either relatively sharp or gradational into the enclosing granodiorite. Rarely, the enclaves are back-veined by the enclosing granodiorite. No systematic regional variation in the nature or abundance of this component has been noted in the pluton. A second, less common, association is as dikes cutting the granodiorite. These dikes may be sharply bound with possible chilled margins but more typically have somewhat gradational and back-veined contacts with the granodiorite. A third association is as irregular masses and dikes that enclose amoeboid masses of granodiorite that are megascopically identical to the granodiorite that encloses the dioritic component. The mutually intrusive relationships and amoeboid forms described above are interpreted to indicate that the granodiorite and dioritic components of the pluton coexisted as magmas.

Ultramafic clots are also widely distributed but are volumetrically insignificant. They are generally small (typically <2 cm but ranging up to 10 cm) and have equant to slightly oblate forms. They are interpreted to be cognate inclusions based on their mineralogy and wide distribution.

Granitic pegmatitic to aplitic dikes are relatively abundant (up to 30% of some outcrops) in the immediate vicinity of the margin of the pluton but are exceedingly rare to absent in the interior of the pluton. Similar dikes also occur in the immediately adjacent country rocks. The origin of these dikes is not certain; they may be related to a late hydrous fluid phase of the Cedar Lake pluton or they may be related to other regional magmatic events and concentrated within zones of late heterogeneous strain localized at pluton contacts.

Planar fabrics, though not ubiquitous, are widely distributed within the pluton. The most obvious manifestation of a planar fabric is the generally well-developed preferred orientation of dioritic enclaves and ultramafic clots (Plate 5). In some cases, there is no discernable mineral foliation associated with the enclave orientation. In a few cases, a weak mineral foliation is developed parallel to the enclave orientation but the fabric deflects and wraps around the enclaves. Most commonly, there is a weakly to moderately well developed mineral foliation that is parallel to and transects the enclaves. The orientation of these fabrics is sub-parallel to the contacts of the plutons but the distribution of outcrops also allows that many of these fabrics are subparallel to regional deformational fabrics in the country rocks. There are several outcrops, however, that have fabric orientations that are highly divergent from regional trends and parallel to the pluton boundaries. These observations are interpreted to indicate that a component of the fabric is related to magmatic flowage and that this fabric is typically overprinted by a

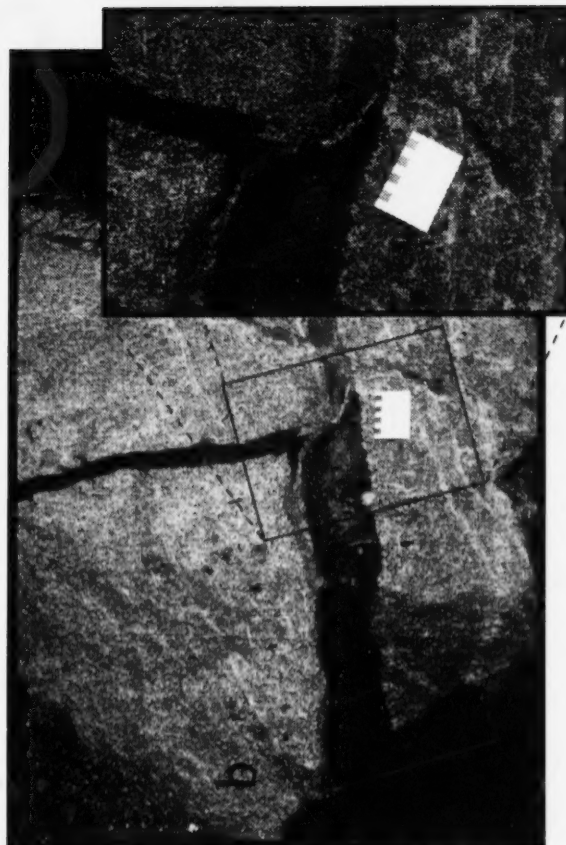


Plate 4. Cedar Lake Pluton.

- Photo "a". Cuspate-lobate granodiorite intrusion within a diorite mass intruding similar granodiorite.
- Photo "b" and inset. Diorite dike intruding and back-veined by the host granodiorite.
- Photo "c". Diffuse, back-veined contact of a diorite dike cutting granodiorite.

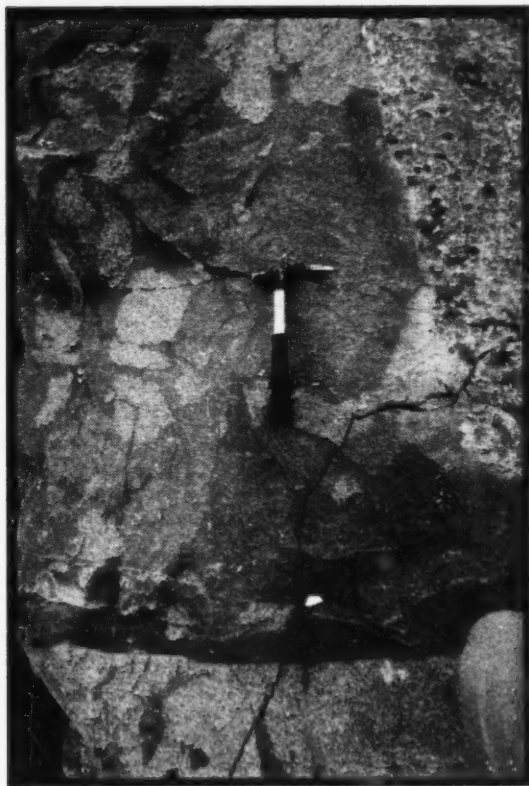
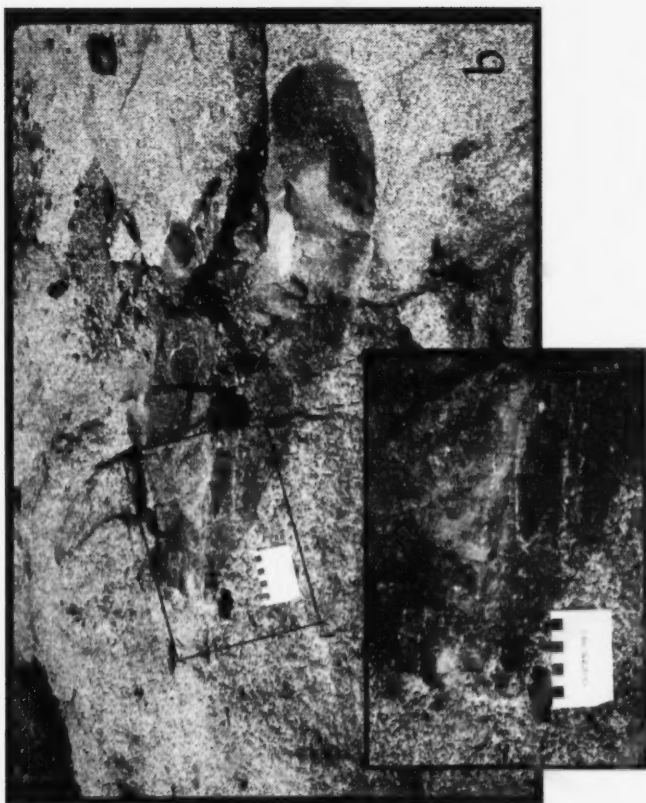


Plate 5. Cedar Lake pluton.

- Photo "a". Pillow-form granodiorite masses within a diorite dike. The granodiorite masses internal to the diorite dike are texturally and compositionally similar to the host granodiorite.
- Photo "b" and inset. Back-veined diorite enclave within granodiorite. Similar ultramafic clots occur in both the diorite and granodiorite.
- Photo "c". Oriented dioritic enclave and ultramafic clots.

tectonic deformational fabric. The scarcity of outcrops near north trending pluton contacts renders it problematic to interpret whether the tectonic deformational fabric is imposed by the pluton itself during continued emplacement during crystallization or is imposed on the pluton by subsequent regional deformational events.

The main granodiorite component of the pluton has a U-Pb zircon age of 2688 ± 3 Ma which is within error of that for the marginal magnetic granodiorite phase (2687 ± 3 Ma) (Corfu and Muir, 1989a). An attempt to constrain the age of the diorite component and test the co-magmatic interpretation was unsuccessful due to the absence of good quality zircon. The diorite contains relatively young sphene (2675 ± 5 Ma) that is interpreted to reflect regional cooling and not magmatic crystallization.

Heron Bay Pluton

The Heron Bay pluton is comprised predominantly of three mineralogically similar, texturally gradational granodioritic phases with local occurrences of volumetrically insignificant dioritic enclaves and ultramafic clots. The three granodiorite phases, referred to as the medium grained granodiorite, transitional granodiorite and plagioclase sub-porphyritic granodiorite, have similar relationships and are discussed together in this section. Very few dikes occur either within or marginal to the pluton.

Mapping carried out as part of this study established that screens of supracrustal rocks previously identified in the pluton (Muir, 1982a,b) are more extensive and continuous than hitherto appreciated. Consequently, the northeastern portion of the pluton, in the vicinity of Rous Lake, may be largely physically isolated from the main mass of the pluton by a narrow septum of supracrustal rocks. The similarity and intergradational nature of the rock types, together with their close proximity, still supports treating these potentially physically separate (at the present level of exposure) entities as the same pluton.

The plagioclase subporphyritic variety of granodiorite occurs primarily in the eastern part of the pluton, including most of the Rous Lake lobe, as well as a narrow zone along the northwest contact of the pluton. The medium grained granodiorite is widely distributed but is centered in the western portion of the pluton. The texturally transitional granodiorites are widely distributed. No crosscutting relationships between these various textural varieties (Plate 6) of granodiorite have been observed. This, together with similarities in their composition and nature of entrained enclaves, suggests that the three phases are genetically related.

The dioritic enclaves and ultramafic clots are similar to those in the Cedar Lake pluton except for being smaller and far less abundant. They may have similar origins to those proposed for the Cedar Lake pluton although diagnostic evidence for a co-magmatic origin of diorite and granodiorite as discussed for that pluton are not recognized in the Heron Bay pluton.

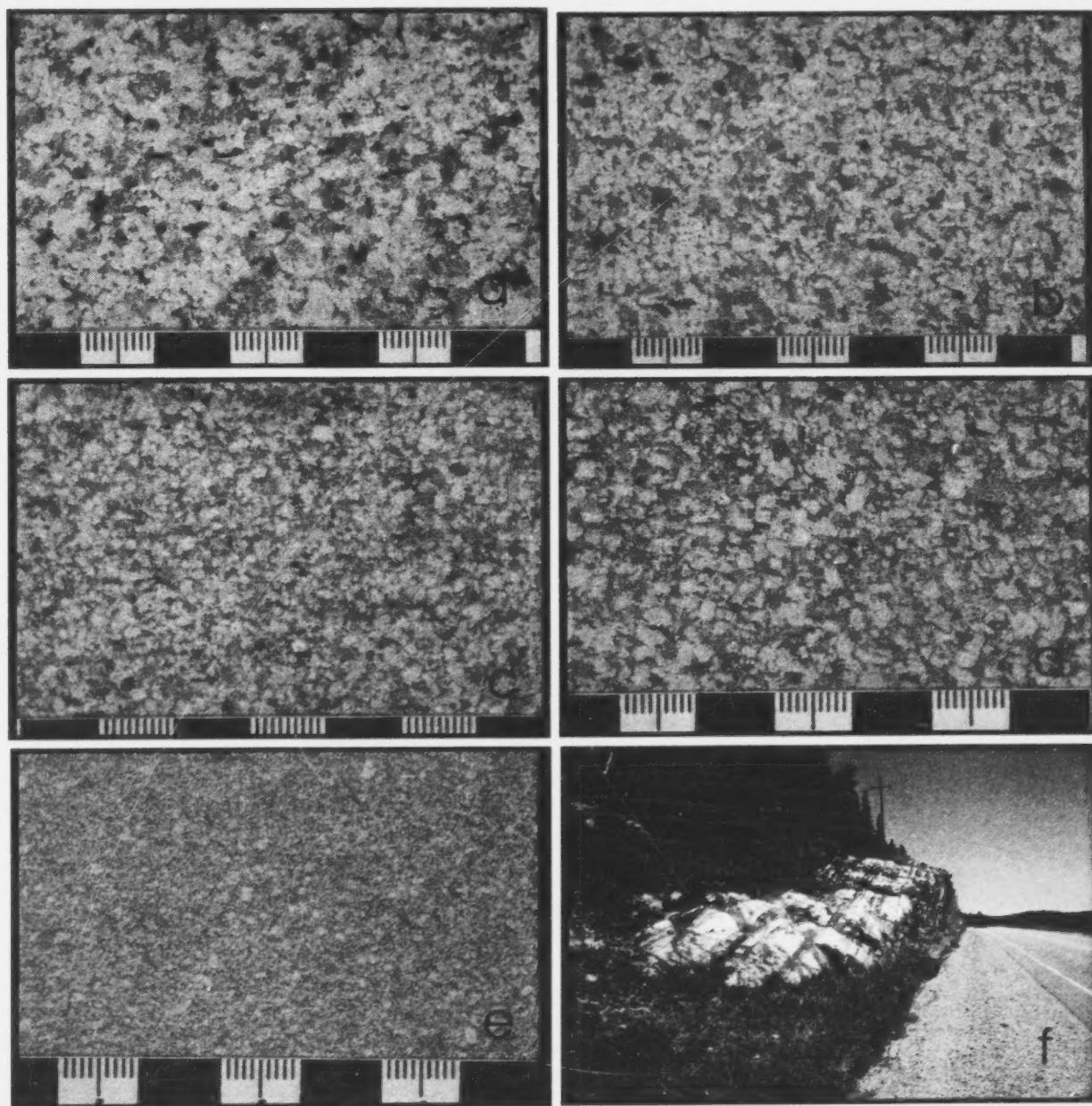


Plate 6. Photos of stained rock slabs illustrating the textural characteristics of medium grained (a), transitional (b) and plagioclase subporphyritic (c and d) phases of the Heron Bay pluton. The habit of plagioclase phenocrysts for plagioclase porphyry dikes from the Hemlo gold deposit area (e) is similar to that displayed by the plagioclase subporphyritic phases of the pluton. The feldspar porphyry dikes (f) are a volumetrically significant component of the deposit area and indicate local extension concomitant with magmatic activity.

Dikes within and marginal to the Heron Bay pluton are not common. Granitic aplitic/pegmatitic dikes occur near the eastern end of the pluton but these are also proximal to the greenstone belt – Pukaskwa batholith contact which is characterized by these types of dikes along much of its length. Consequently the dikes in this area are interpreted to be related to a more regional magmatic event and not the Heron Bay pluton. In one outcrop in the eastern portion of the pluton, a finer grained, but otherwise texturally similar, feldspar porphyry dike cuts plagioclase subporphyritic granodiorite. This dike may be a late, quenched phase of the Heron Bay pluton.

The form of the Heron Bay pluton mimics the pattern of regional folding of stratigraphy and the D_1 deformational fabric in the surrounding greenstone belt (Jackson, 1998). Planar tectonic fabrics have not been identified in the pluton and enclave orientations vary from random to well developed, especially near the contacts of the pluton. In one outcrop, near Rous Lake, a plagioclase subporphyritic variety of granodiorite is observed to sharply crosscut the regional D_1 fabric of the greenstone belt with dike-like feldspar porphyry apophyses (Plate 7). These observations are interpreted to indicate that the emplacement of the Heron Bay pluton post-dates the development of the regional deformational fabric (D_1). As discussed below, emplacement may be synchronous with regional folding (D_2) of the greenstone belt and D_1 fabric.

Previous efforts to determine a U-Pb zircon age for the Heron Bay pluton (Corfu and Muir, 1989a) were hampered by poor zircon yield, requiring these authors to analyze fractions from two separate samples from near Rous Lake and just south of the supracrustal septa to the south of that lake. The resultant age (2688 ± 5 Ma) is comparable to that of other discrete plutons and minor intrusions in the area (Table 2). An additional sample was selected from the outcrop of plagioclase subporphyritic granodiorite displaying the crosscutting relationship with respect to the D_1 deformational fabric (Plate 7). Preliminary data includes several concordant or near concordant zircon fractions with $^{206}\text{Pb}/^{207}\text{Pb}$ ages between 2688 and 2692 Ma. Another sample from a medium grained granodiorite phase in the center of the western portion of the pluton has yielded a preliminary indication of an approximate magmatic age of 2690 Ma although this interpretation is hampered by the presence of both inherited and metamorphic zircon in this sample. A reasonable estimate for the age of the Heron Bay pluton in the light of the previous and new data is approximately 2688 to 2690 Ma. This age also places a minimum age constraint on the timing of D_1 fabric development.

Gowan Lake Pluton

The Gowan Lake pluton is an arcuate pluton emplaced along the northern contact of the Hemlo greenstone belt, separating the latter from the Black-Pic batholith in this area. The main phases of the pluton exhibit considerable compositional (diorite – quartz monzodiorite – granodiorite; color index 15 to 40) and textural (equant to acicular amphibole; equigranular to porphyritic to microcline-megacrystic) diversity but these rock types appear to be intergradational and distinct contacts between rocks with various combinations of these characteristics are rare. The acicular nature of the amphibole in some rocks is a distinctive feature, similar in certain respects to that seen in some of the

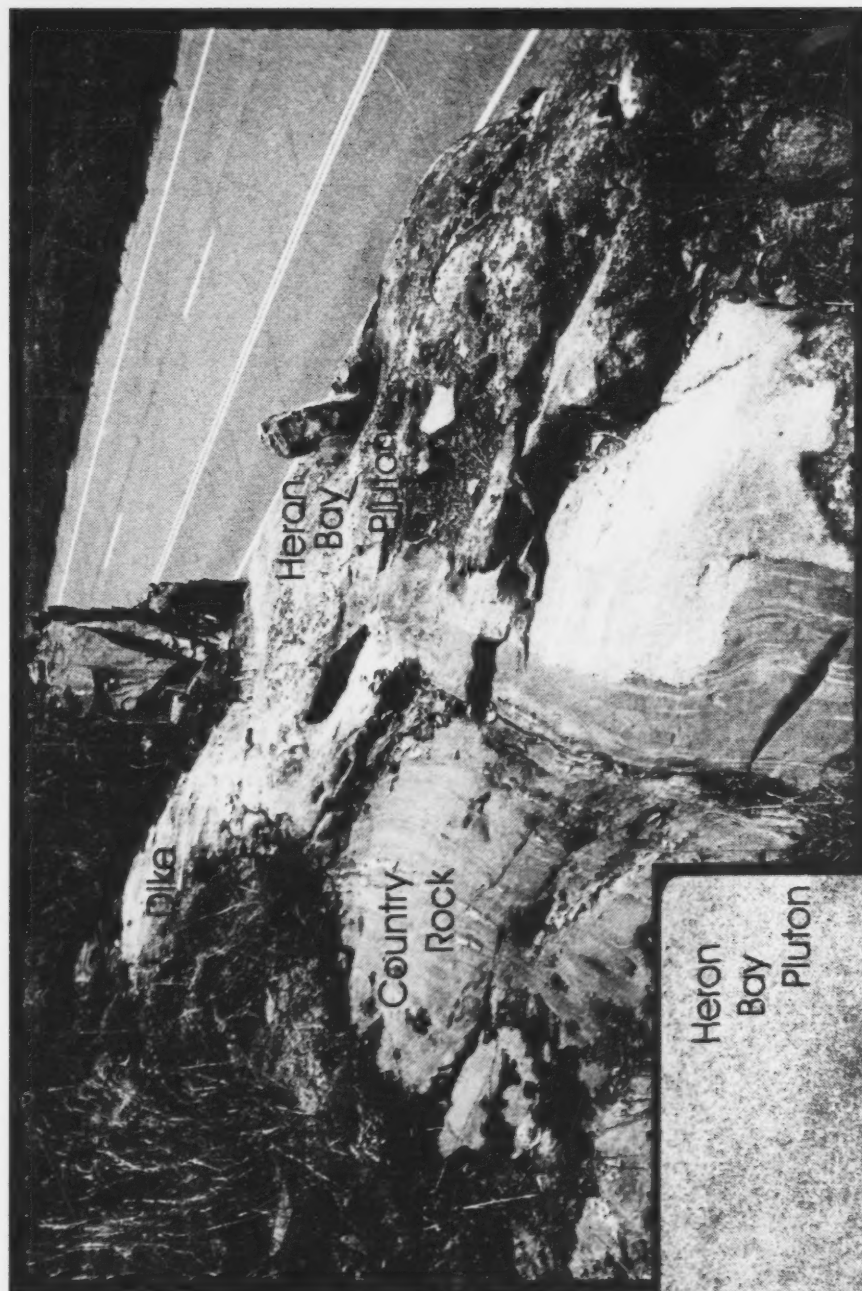


Plate 7.. Contact relationships at the margin of the Heron Bay pluton east of Rous Lake. The width of the foreground of the overview photo is approximately 3 meters. The inset photo (from the foreground of the overview photo illustrates the cross-cutting relationship with the D1 fabric.

(appinite suite?) intermediate to mafic dikes in the Black-Pic batholith. All of the rock types contain abundant dioritic to quartz monzonitic enclaves and ultramafic clots that are invariably more mafic than their host. Dikes of any sort are rare.

The main phases typically display patchy irregular compositional variation, particularly in color index, that may reflect inefficient mixing of different magma compositions. In several outcrops reasonably well developed compositional and textural layering suggests that some of the variation may reflect in situ magmatic differentiation (Plate 8). The texture of the main phases ranges from equigranular to weakly plagioclase and/or amphibole porphyritic to K-feldspar megacrystic. Similarities in mineralogical characteristics, together with their intergradational nature suggests that these phases are closely related despite their diversity.

Dioritic to quartz monzonitic enclaves are abundant, typically constituting 2 to 5 percent and locally up to 10 percent of outcrop areas. The abundance of these enclaves is unusual and is a distinctive feature that distinguishes this pluton from others in the Hemlo area. Enclave boundaries may be sharp or diffuse; in some cases the boundaries may be so indistinct so as to make it difficult to distinguish discrete enclaves. It is possible that this variation may be an end member of the irregular compositional diversity discussed in the preceding paragraph. There are no other indications that the enclaves may represent mingled magmas and it is also possible that these diffuse contacts are a consequence of mechanical degradation of (thermally softened?) pre-existing rocks. Ultramafic clots are also relatively more abundant than in any other plutons in the Hemlo greenstone belt area. These are tentatively interpreted to be cognate inclusions.

One unusual composite dike observed in the northern part of the pluton has a dioritic central portion with cusped contact with a marginal granodioritic phase. This may reflect incomplete mixing or immiscibility between coexisting magmas. Similar composite dikes have been described by Snyder et al. (1997). Other dikes, even in parts of the pluton immediately adjacent to the Black-Pic batholith which contains abundant late dikes, are rare, suggesting that this may be one of the latest magmatic events in the area.

Planar fabrics, including local magmatic layering, enclave preferred orientation and mineral foliation, are subparallel to the arcuate form of the pluton. Mineral foliations are locally well developed but exhibit local irregularities and deflect around and do not transect enclaves. This is interpreted to indicate that these are magmatic flowage fabrics related to the emplacement of a sheet-like mass along the contact of the greenstone belt.

The Gowan Lake pluton is interpreted to be emplaced late in the overall sequence of deformational events on the basis of presence of magmatic flowage fabrics that appear not to be over-printed by tectonic deformational fabrics. Cross-cutting relationships with respect to regional deformational fabrics were not observed. A previously reported U-Pb zircon age of 2678 ± 2 Ma (Corfu and Muir, 1989a) is consistent with the interpretation that this is one of the youngest major plutons associated with the Hemlo greenstone belt.

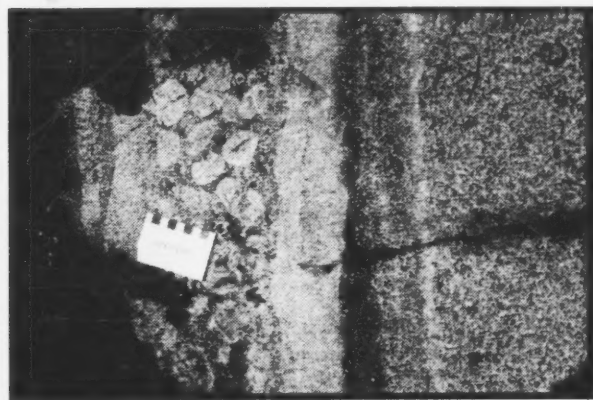
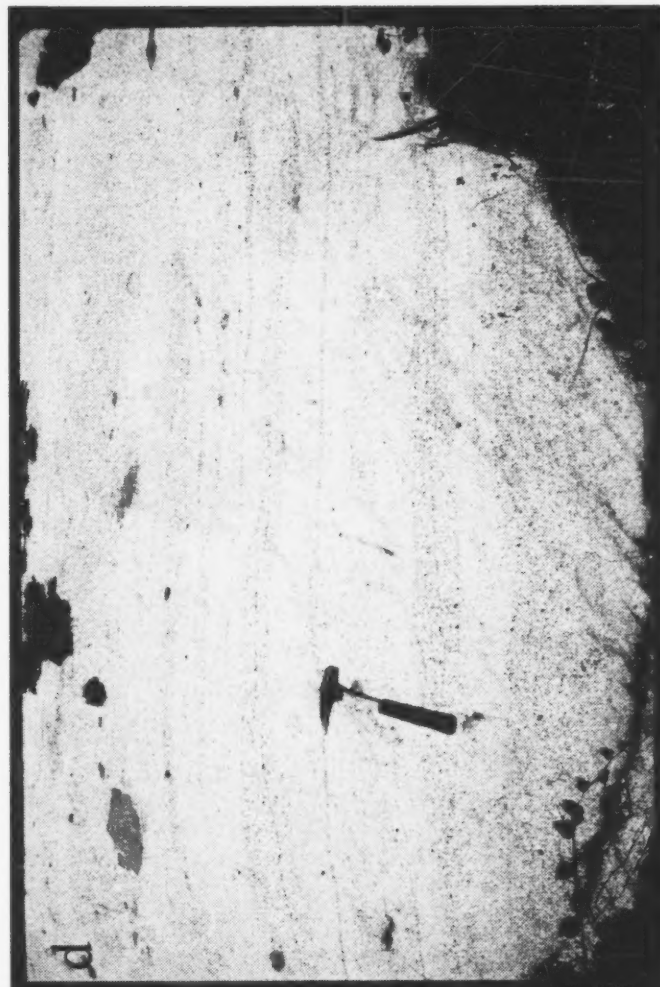
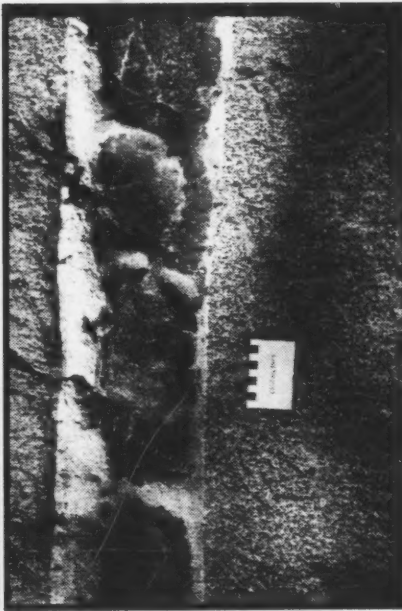
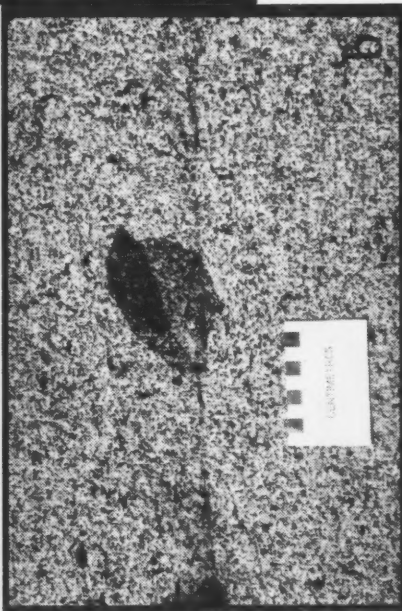
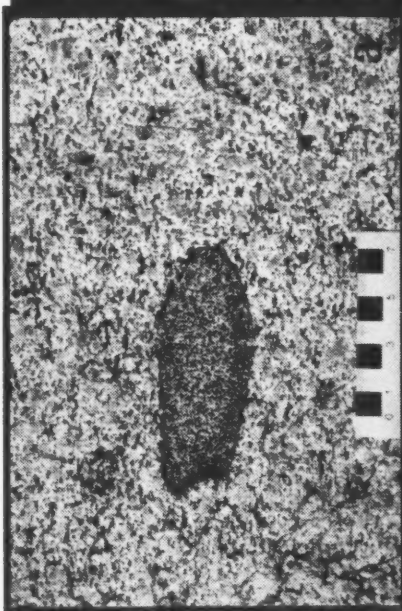


Plate 8. Gowan Lake pluton.

Photo "a". Mafic enclave in microcline megacrystic quartz monzodiorite.

Photo "b". Composite mafic enclave in microcline megacrystic quartz monzodiorite.

Photo "c". Composite (diorite - leucogranodiorite), mixed magma dike cutting equigranular quartz monzodiorite.

Photo "d". Textural/compositional layering with numerous mafic enclaves.

Photo "e". Compositional layering with quartz monzodioritic, gabbroic and porphyritic anorthositic components.

Dotted Lake Batholith

The Dotted Lake batholith is bounded to the north, west and south by mafic metavolcanic rocks of the Hemlo greenstone belt. The eastern contact of this unit lies outside the area investigated but it is presumed to be in contact with the Black-Pic batholith. The batholith is dominated by a single, megascopically homogeneous, biotite leuco-tonalite to leuco-granodiorite. Enclaves or inclusions of any sort are not known to occur and leucogranitic pegmatite dikes are exceedingly rare.

Much of the interior of the batholith is massive to weakly foliated to lineated (Plate 9). The margin of the batholith, however, is highly strained with a well developed penetrative fabric parallel to both the contact and penetrative fabrics in the adjacent mafic metavolcanic rocks. Localized narrow zones of high strain also occur in the interior of the batholith associated with narrow, brittle-ductile shear zones. The batholith is interpreted to pre-date the imposition of the regional (D_1) deformational fabric (Jackson, 1998). The concentration of strain in the marginal area, with large parts of the batholith away from the margin being relatively less deformed, is interpreted to indicate that the size of the batholith, together with the ductility contrast with the adjacent metavolcanic rocks, resulted in the batholith acting as a buttress against which this deformation took place.

A sample selected from the interior of the batholith yielded a U-Pb zircon age of approximately 2697 Ma. This also provides a maximum age constraint on the timing of a component of D_1 deformation.

Fourbay Lake Pluton

The Fourbay Lake Pluton is an elliptical pluton located entirely within the Black-Pic batholith from which it is distinguished by a prominent aeromagnetic anomaly associated with the pluton and its homogeneous, massive character. The unit was examined in a series of exposures along a powerline which crosses the southern portion of the pluton. In that part of the pluton investigated, a massive, compositionally uniform quartz monzodiorite is the sole phase. Dioritic enclaves are a minor component in several outcrops but their abundance is very much less than 1 percent overall. The unit has a preliminary U-Pb zircon age of approximately 2677 Ma.

Musher Lake Pluton

The Musher Lake pluton is internal to the Hemlo greenstone; its extent is poorly constrained due to limited exposure in this area and negligible magnetic contrast with adjacent country rocks. On the basis of the limited exposure, the pluton appears to be uniformly tonalitic with minor, widely distributed dioritic enclaves. The enclaves typically have diffuse contacts with the host tonalite but other features diagnostic of their possible relationship were not noted. A weak mineral foliation is parallel to enclave orientation but it is not clear if this is a tectonic or a magmatic flowage fabric.

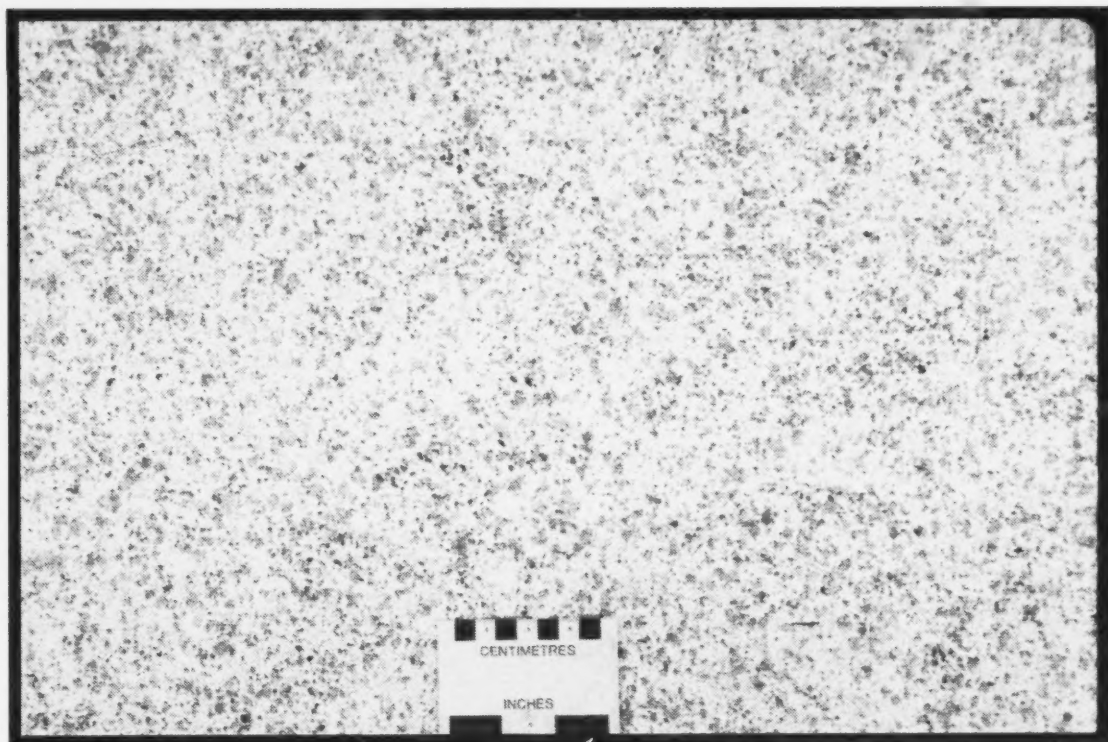


Plate 9. Homogeneous, coarse grained, inclusion-free leuco-tonalite, Dotted Lake batholith.

The northern contact of the pluton is seen in recently exposed exploration trenches. Here, tonalite within a few tens of metres of the contact contains inclusions of highly deformed country rock. The inclusions are sharply bound and relatively angular suggesting that they were incorporated in the magma subsequent to ductile high strain. In several inclusions the strong fabric is deformed into open folds, further suggesting that the pluton was emplaced post D_1 and syn- to post- D_2 (Plate 10). A preliminary U-Pb zircon age for a tonalite from this area constrains the time of emplacement of the pluton (approximately 2679 Ma) and thereby D_1 and, less stringently, D_2 .

Cedar Creek Stock

The Cedar Creek stock is a crudely elliptical internal pluton located west of the Cedar Lake pluton and in close proximity to the Hemlo gold deposit. Large portions of the stock are not exposed but its extent can be inferred on the basis of its strongly magnetic character on regional aeromagnetic maps.

The pluton is composed of massive granodiorite with very rare, small, dioritic enclaves. The granodiorite has a U-Pb zircon age of 2864^{+4}_{-3} Ma (Corfu and Muir, 1989a). A very weak foliation may be present near the southern boundary of the pluton where it is parallel to the pluton contact (Muir, 1997) but overall the pluton is largely massive.

Satellite Stock

A small stock located several kilometres north-north-west of the Cedar Creek stock is informally referred to here as the Satellite stock. The stock is poorly exposed and is interpreted to be a small, crudely elliptical stock on the basis of a prominent aeromagnetic anomaly, the nature of which invites comparison with the nearby Cedar Creek stock.

On the basis of limited exposure, the stock is comprised of granodiorite with some diorite. Both rock types appear to be massive and their relationship to each other and the country rock is not understood.

Melgund Stock

The Melgund stock is a small, somewhat irregularly shaped pluton that intrudes metavolcanic and metasedimentary rocks in the area between the Gowan Lake and Heron Bay plutons. The pluton coincides with a prominent positive topographic feature that closely outlines the geometry of the pluton.

The pluton is comprised of tonalite with widespread, volumetrically minor dioritic enclaves and very minor ultramafic clots. All of the phases appear to be massive. Contact relationships with country rock are not exposed.



Plate 10. Musher Lake pluton.

- Photo "a". Folding of strong fabric within an inclusion in the Musher Lake pluton.
- Photo "b". Strong deformational fabric within a sharply bounded inclusion.
- Photo "c". Dike cross-cutting deformational fabric within meters of, and possibly related to, the Musher Lake pluton.

Ogilvie Island Pluton

The Ogilvie Island pluton is exposed on an island in Lake Superior and consequently its extent and relationship to country rock are unknown. The only phase noted is a massive granodiorite that is apparently devoid of inclusions.

Picture Island Stock

The Picture Island stock is exposed on the shore of Lake Superior. It intrudes mafic metavolcanic rocks of the Hemlo greenstone belt but it lies very near the contact with the Pukaskwa batholith.

The stock consists of granodiorite with minor quartz dioritic enclaves. A weak foliation of indeterminate origin is developed through most of the stock and, locally, the granodiorite is highly deformed in narrow discrete dextral shears. In several cases, well developed mylonitic fabrics are associated with these zones. Speculatively, this localized shearing and mylonitization might be related to the intense strain associated with the greenstone belt – Pukaskwa batholith contact.

White River Pluton

The White River pluton is a small, tabular body intruding metavolcanic rocks south of the Cedar Lake pluton. Previous investigation (Siragusa, 1984a) interpreted the unit from numerous, small outcrops to be a massive syenite. The younging direction of the supracrustal sequence that contains the White River pluton is poorly constrained (no top indicators are shown on maps (Siragusa, 1984a, b) although it has been suggested, based on regional considerations, that the sequence is an overturned south-facing monocline (Siragusa, 1983).

Examination along a single transect through the pluton suggests that the unit is moderately well foliated and exhibits a systematic lithologic heterogeneity. The northern margin of the unit was found to be composed of heterogeneous, relatively melanocratic (C.I.~50) monzodiorite and the central and southern portions of the unit underlain by less mafic (C.I.<30) quartz monzodiorite. Further work would be required to establish the consistency of this relationship, but it is possible that this relationship may be indicative of this unit being an early differentiated sill. This in turn would suggest that the south side of the unit might correspond to the top of an originally sub-horizontal sill. This would be consistent with the southward younging hypothesis of Siragusa (1983). Mineralogical and geochemical data collected to test this hypothesis are discussed in a subsequent section.

Botham Stock

The Botham stock (Muir, 1997) is a small, composite intrusion located several kilometres west of the Hemlo gold deposit and comprised of two distinct phases. One of these is a fine grained, well foliated, altered, feldspar porphyry whereas the other is a medium grained, equigranular to plagioclase subporphyritic, relatively fresh and unaltered

granodiorite. The two rock types have not been observed in contact but on the basis of their contrasting texture, alteration and deformational state, they are interpreted to be temporally and perhaps genetically distinct. Preliminary age determinations of approximately 2688 (zircon) and 2672 Ma (sphene) (Davis et al., 1998) for the medium grained variety are closely comparable to other age determinations for the Hemlo gold deposit area (e.g., Heron Bay pluton, Cedar Lake pluton).

Minor Intrusions

Deformed Quartz-Porphyritic Rocks (including Moose Lake Porphyry)

Fine grained quartz $\pm$ feldspar porphyry exhibits a close spatial relationship with many of the known gold occurrences in the Hemlo greenstone belt (Schnieders et al., 1993). The Hemlo gold deposit has been interpreted as a porphyry-style deposit genetically linked to the Moose Lake porphyry complex (Kuhns, 1988; Kuhns et al., 1994; Johnston, 1996). Consequently, an understanding of the timing and nature of these units is critical in constraining possible linkages to mineralization. The Moose Lake porphyry is the subject of detailed investigations carried out as part of the CAMIRO investigation but most surface, and some underground, exposures were examined as part of this study to contribute to an understanding of unit and enable comparison with rocks elsewhere in the greenstone belt. Other occurrences near Heron Bay and immediately north of the Musher Lake pluton were investigated briefly.

The Moose Lake porphyry is strongly deformed and altered. These characteristics obscure primary features indicative of the origins of this unit that has led to considerable controversy. For example, Johnston (1996) considered the Moose Lake porphyry complex to be a multiphase intrusive complex that intruded metasedimentary rocks subsequent to their folding. Local fragmentation is attributed to hydrothermal brecciation. Muir (1997) includes the Moose Lake porphyry of Johnston (1996) within a more extensive unit, characterized throughout by the presence of quartz phenocrysts, that includes both massive as well as fragmental and/or layered varieties. Muir (1997) interprets much of the fragmentation and layering to be of a volcanoclastic origin. For the purpose of this investigation, most of the effort was focused on the portion of the quartz porphyritic unit having a higher proportion of massive quartz porphyritic rocks of possible intrusive origin, corresponding to the more restricted geographic extent of the Moose Lake porphyry complex of Johnston (1996). In subsequent discussion, Moose Lake porphyry (MLP) refers to this more geographically restricted unit whereas the more extensive quartz porphyritic rocks (including the MLP) are referred to as the quartz porphyritic unit (QPU).

The following observations and interpretations pertaining to the quartz porphyritic unit (QPU) and Moose Lake porphyry (MLP) were made as part of this study:

- 1- The MLP includes both massive and fragmental varieties whereas fragmental varieties predominate in those portions of the QPU not included in the MLP. The mechanism of fragmentation in the MLP is generally indeterminate but is

- locally associated with layering defined by fragment size variation, suggesting that the unit is, at least in part, supracrustal as suggested by Muir (1997).
- 2- The most significant occurrences of the massive quartz porphyritic rocks are within the MLP, coinciding with the central, thickest portion of the QPU.
 - 3- Feldspar phenocrysts commonly coexist with quartz phenocrysts but are typically moderately to intensely altered. Variation in the apparent relative proportions of the two phenocryst phases is interpreted to reflect a range of development of feldspar destructive alteration more so than a range of primary abundance.
 - 4- The texture and mineralogy of the massive portions of the MLP are closely comparable to that of the fragments in both the fragmental portions of the MLP as well as the broader QPU as noted by Muir (1997).
 - 5- The MLP is nowhere observed to crosscut stratigraphy or tectonic fabrics and is interpreted to have undergone the same complex deformational history as the adjacent metasedimentary rocks. This interpretation is similar to that of Muir (1997) and at odds with that of Johnston (1996).
 - 6- No crosscutting relationships between different quartz porphyritic phases (other than late quartz-feldspar porphyritic dike described in next section) have been observed. Abrupt color changes from grey to red or pink observed in the subsurface of the Williams Mine and south wall of the Williams A Zone pit are attributed to alteration along fractures. As discussed above, local variation in the abundance of plagioclase phenocrysts is attributed to variously developed feldspar destructive alteration.

On the basis of these observations and interpretations, the QPU is interpreted to be a felsic volcanic unit that includes an endogenous dome component that is approximately represented by the MLP. Within this context, the MLP may be in part intrusive but is shallow level, synvolcanic and pre-tectonic.

The absolute age of the Moose Lake porphyry has been the subject of several investigations. Corfu and Muir (1989a) reported an age of 2772 ± 2 Ma whereas Johnston (1996) reports a range of $^{207}\text{Pb}/^{206}\text{Pb}$ ages for zircon (Table 2) suggesting that the unit is considerably younger and incorporates diverse xenocrystic zircons. Davis (1998) investigated several of the quartz porphyritic units and concluded that these rocks contain abundant inherited zircons as old as ca. 2800 Ma but most samples had younger zircons indicating a maximum depositional age of ca. 2690-2695 Ma. The interpretation offered here for the relative age of this unit is that, barring unconformable relationships, it should be comparable in age to the adjacent metasedimentary/metavolcanic rocks. Regionally, metasedimentary rocks are interpreted to be relatively young (2688 to 2693 Ma, Davis et al., 1998, Jackson, 1998) and with similar ages reported for metasedimentary rocks in the vicinity of the Hemlo gold deposit (Davis, 1998).

Deformed quartz porphyritic rocks also occur elsewhere in the belt, most notably immediately north of the Musher Lake pluton and near the town of Heron Bay. The former was not investigated in detail but appears to have many features in common with the QPU at Hemlo. The occurrences of these rocks near Heron Bay are not well exposed

but include a massive, altered and deformed, quartz-feldspar porphyry of possible shallow level intrusive origin (Muir, 1982b).

Dike Rocks

Dike rocks are a heterogeneously distributed, minor, but locally abundant, component in the Hemlo greenstone belt. One of the most notable concentration of dike rocks occurs in the immediate vicinity of the Hemlo gold deposit (Muir, 1997). Regionally, they exhibit considerable compositional and textural diversity that, together with their extent, precluded a comprehensive, systematic evaluation of their characteristics and origin. The approach adopted for this study was to investigate intermediate to felsic dikes occurring in the Hemlo gold deposit area that may be genetically related to the larger nearby intrusions. More mafic varieties of dikes were not investigated. A number of dikes from other areas of the Hemlo greenstone belt exhibiting similar field relationships, compositions and textures to those investigated near the Hemlo gold deposit were also studied.

In the Hemlo gold deposit area, the following types of dikes were investigated:

- 1- Feldspar porphyry dikes- These are by far the predominant variety in the area.
- 2- "Popcorn" porphyry dikes- These rare dikes are characterized by the presence of larger (<1 cm diameter), more irregularly shaped feldspar phenocrysts than the more common variety of feldspar porphyry.
- 3- Aphyric dikes- These are a volumetrically minor phase.
- 4- Quartz-feldspar porphyry dikes- These are rare with the only examples found being from the west end of the Hemlo gold deposit area.

All of these dikes are interpreted to have similar relative age relationships with respect to the sequence of deformational events in the Hemlo gold deposit area. The subsequent discussion, however, is based on observations and interpretations that apply to the feldspar porphyry dikes as the limited occurrence of the other varieties renders their interpretation more ambiguous.

The feldspar porphyry dikes occur as tabular bodies ranging in thickness from several centimetres to several tens of metres. Most are between 10 and 100 centimetres thick. The dikes are subparallel to the regional fabric in the host rocks although subtle discordance is commonly noted and higher angle discordance is observed in the noses of some folds where the dikes are parallel to the axial surface of these folds (Muir, 1997). The dikes also carry a weak to moderately well developed fabric parallel to the axial surface of these folds which is interpreted to reflect the emplacement of these dikes during the waning stages of the (Hemlo deposit area) D₂ deformation that produced the folds (Muir, 1997). Alternatively, the deformation of the dikes could be attributed to development of a later, coplanar fabric. This latter explanation is favored because the emplacement of the sheeted feldspar porphyry dikes requires extension approximately perpendicular to the direction of maximum compression inferred from the fabrics. The

dikes are also interpreted to post-date alteration and gold mineralization (Muir, 1997). Observations made as part of this study are consistent with this interpretation except for:

- 1- The dikes typically have pervasive disseminated carbonate (1-5 percent). It is not known if this is a late superimposed alteration event or an autometasomatic effect indicating late CO₂-rich magmatic fluids.
- 2- The margin of a thick dike exposed in the David Bell Mine is transected by sodic, feldspathic alteration with associated pyritic mineralization suggesting that a minor component of alteration and mineralization post-dates the emplacement of these dikes. It is probable that this alteration/mineralization is a late, minor event unrelated to the initial formation of the deposit.

The matrix of the dikes is finer grained than any of the larger plutons in the area, but the grain size (~2-3 mm) and equant form of the plagioclase phenocrysts is closely comparable to that of plagioclase in the plagioclase subporphyritic phase of the Heron Bay pluton and the medium grained phase of the Botham stock. At an exposure of the contact of the Heron Bay pluton on the highway just east of Rous Lake, a dike-like apophyse of the pluton has a similar form (Plate 7) and composition to the feldspar porphyry dikes. Previous U-Pb zircon age determinations for a feldspar porphyry dike from adjacent to the Cedar Lake pluton (2687 ± 3 Ma) and a diorite dike from the deposit area (2680 to 2690 Ma) (Corfu and Muir, 1989a) are closely comparable to the ages of some of the larger plutons in the area including the Heron Bay pluton and Botham stock.

Pegmatitic – Aplitic Dikes

Pegmatitic and aplitic dikes of leuco-granitic and, less commonly, leuco-granodioritic to leuco-tonalitic composition are locally abundant, particularly in the Black-Pic and Pukaskwa batholiths and near some of the contacts of internal stocks. The distribution of these rocks has been briefly described above with reference to individual intrusive units and their general characteristics are described here.

The geometry and internal form of the dikes is highly variable. Many are regular tabular bodies but some are irregular vein-like bodies. They may be internally uniform or exhibit textural and/or mineralogical zoning. Common types of zoning include; pegmatitic margins with interior aplite, aplitic margins with interior pegmatite and granitic pegmatitic margins with quartz-rich interiors.

The dikes range from being strongly deformed to undeformed but it is generally difficult to attribute their deformation to specific regional deformational events. This is particularly true for dikes concentrated at pluton contacts that may be loci of late deformation post-dating the main regional deformational events. In the Black-Pic and Pukaskwa batholiths, pegmatitic and aplitic dikes are more uniformly distributed and consistently display a range of intensity of superimposed deformation, suggesting that the emplacement of these rocks occurred throughout at least the later portion of the main regional deformations that affected these batholiths.

The ultimate source of the pegmatitic/aplitic dikes is problematical. Their abundance in the belt-bounding batholiths suggests that these may be centres with which this type of intrusive activity was associated. The concentrations of these rocks along various granite-greenstone contacts (notably the south-west contact of the Cedar Lake pluton) may be a reflection of dilatancy caused by local, late heterogeneous strain focused in areas of high ductility contrast.

All of the massive plutons have hydrous mafic minerals and hydrous deuteritic alteration products suggesting that they were hydrous and evolved late, hydrous magmatic fluids, but none of these display interior zones of more evolved, diffusely bounded pegmatitic phases. The hydrous magmatic volatile phase could have been either completely or partially consumed by deuteritic alteration reactions. Any remaining fluid would presumably escape the plutons to intrude or react with adjacent country rocks. This is a plausible mechanism to form some of the pegmatitic/aplitic dikes. However, on the basis of the lack of internal evolved pegmatitic zones in the plutons and the presence of erratically distributed minor pegmatite/aplite well removed from any plutons, a regional, rather than pluton localized, pegmatite/aplite magmatic system may be more plausible.

Petrology, Geochemistry and Petrogenesis of Intermediate to Felsic Intrusive Rocks

This section describes the major mineralogical and textural characteristics, together with distinctive geochemical characteristics, of the principal rock types. The observations and conclusions discussed here are based on field observations, examination of stained slabs and polished thin sections augmented by limited electron microprobe analyses and whole rock geochemical analysis. Petrogenetic interpretations are offered for some units.

Petrographic and detailed modal analyses, together with whole rock geochemical analyses, confirm and refine the distinction of discrete intrusive bodies identified on the basis of fieldwork. The data further suggest that many discrete intrusive bodies, though having certain distinctive characteristics, may be assigned to different granitoid suites that may be temporally and genetically related. Some of the general and distinctive mineralogical and geochemical features are summarized in Table 3. These observations support a general subdivision of the granitoid rocks into suites that have differing characteristics and petrogenesis. Discussion of provisionally defined suites, together with discussion of possible interrelationships, follows.

Gneissic Tonalite Suite

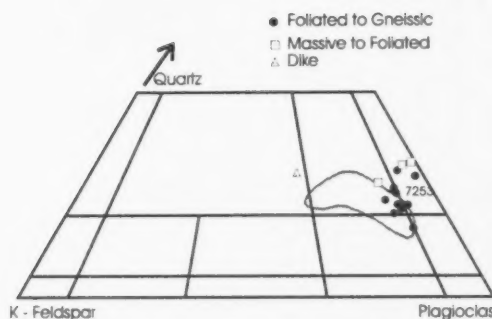
This suite is comprised of gneissic to foliated granodioritic to tonalitic rocks occurring in the Black-Pic and Pukaskwa batholiths. Most of these rocks are characterized as heterogeneous, foliated to gneissic metaigneous rocks that lie in the IUGS modal compositional range of tonalite to K-poor granodiorite (Figure 3). In addition, some of the more homogeneous rocks of similar composition containing a weakly to moderately developed tectonic fabric and characterized as massive to foliated plutons have similar characteristics and are assigned to this suite. Color index ranges between 5 and 15 for

Table 3. Summary of general mineralogical and geochemical characteristics of intermediate to felsic rocks representing the main phases of intrusions associated with the Hemlo greenstone belt. Terms such as low, moderate or high refer to abundances relative to that occurring in other units associated with the Hemlo greenstone belt and not with respect to granitoid rocks in general. Ranges that characterize or dominate within a unit are indicated in bold type whereas unbolded type indicates anomalous data or insufficient consistency to establish a characteristic range. The ranges in rounded brackets for the Heron Bay pluton is that for a small subset of the data from the extreme northwest portion of the pluton.

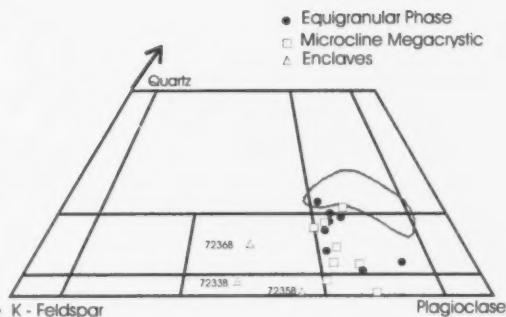
Unit	IUGS Rock Type	ColorIndex - {H/HBC}	SiO ₂ Mg #	Mg#	ACNK	TiO ₂	Yb _N	Ce _N /Yb _N	Ce _N	Eu/Eu*	Distinctive geochemical features
Pukaskwa gneissic units	Tonalite/ Granodiorite	7-14 {0-84}	67-71	34-47	0.97- 1.01	0.24- 0.38	1-3X 8X	20-35 14-52	45-90	0.91-1.10 1.29	Low K, Rb, Sr, Zr, Y, Ni, Cr
Pukaskwa massive units	Tonalite/ Granodiorite	10-18 {0-86}	64-70	38-51	.93 0.85- 1.04	.46 0.30- 0.46	2X, 4X, 6X	20, 24, 88	50, 70, 200	0.87-1.02	Low K, Rb, Sr, Zr, Y, Ni, Cr
Black Pic gneissic units	Tonalite/ Granodiorite	5-11, 14 {0-14, 97}	67-71	38-46 .51	0.98- 1.03	0.14- 0.24	<2X	17-30 .65, 90, 116	100-140 60-140	1.07-1.38	Low K, Rb, Sr, Zr, Y, Ni, Cr
Black-Pic massive units A	Granodiorite	5-16, 21 {0-59, 78}	64-70	36-52	0.88- 1.01	0.31- 0.56	<4X	21-44 .94	60-110X	1.01-1.04 .92	Low K, Rb, Sr, Zr, Y, Ni, Cr
Black-Pic massive units B	Quartz Monzodiorite/ Monzodiorite	23-38 {78-96} rare cpx	54-63	49-60	0.70- 0.93	0.60- 0.76	9-11X .4X	10-14 .37	110- 140X	0.87-0.93	Moderate K, P
Dotted Lake Batholith	Granodiorite/ Tonalite	2-7, 10 {0, 30}	69-74	36-43 .47	1.01- 1.06	0.11- 0.24	1-3X	7-22	15-30X	1.03-1.30 .91, 1.43	Low K, Ca, Rb, Sr, Zr, Y, Ni, Cr, Th, U High Na

Table 3. (continued)

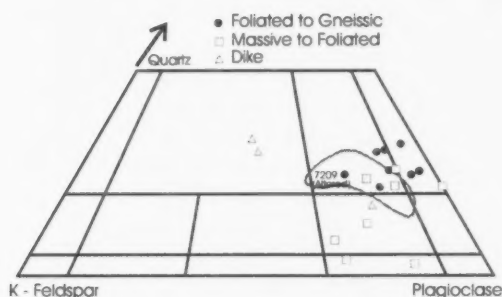
Unit	IUGS Rock Type	ColorIndex - {H/HBC}	SiO ₂	Mg #	ACNK	TiO ₂	Yb _N	Ce _N /Yb _N	Ce _N	Eu/Eu*	Distinctive geochemical features
Cedar Lake Pluton	Granodiorite/ Quartz Monzodiorite	8-19, 6 {59-82, 49,9}	62-67	45-56	0.88- 0.96	0.38- 0.58	3-6X	32-64	120- 180X	0.86-0.96	Moderately high P, Ba, Y, Zr, Nb, Th, Ni
Heron Bay Pluton	Granodiorite	7-17, 24,27	65-69	42-49	0.92- 0.99 (0.84- 0.88)	0.27- 0.44	1-4X	14-42	230 30-80X	0.92-1.22	High Sr Relatively low Ca except for NW part of pluton
Gowan Lake Pluton	Quartz Monzodiorite/ Monzodiorite/ Granodiorite	{45-79,92} 17-28, 14 {59-95,51} minor cpx	(62,63) 55-63	(56,57) 45-51	0.80- 0.89	0.51 0.50- 0.77	(4-6X) 8-11X	16-20	130- 200X	0.85-0.97	High Fe, Mg, Mn, P, Ba, Rb, Y, Zr, Nb, Th, V, Ta, Co, U
Cedar Creek Stock	Granodiorite	5-8	67-69	38-41	0.94- 0.98	0.35- 0.42	13X	33.58	80-120X	0.95-1.03	Low Mg# and Ca
Fourbay Lake Pluton	Quartz Monzodiorite	{15-45} 14-20 {68-85} minor cpx	60-63	44-47	0.85- 0.87	0.50- 0.61	8-11X	21-56	160- 220X	0.87-0.91	High Fe, Mg, Mn, P, Ba, Rb, Y, Zr, Nb, Th, V, Ta, U
Musher Lake Pluton	Granodiorite	16-23 {39-54,72}	62-65	47-50	0.92- 1.00	0.49- 0.62	4-6X	19-25	90-130X	0.89-0.99	Moderately high P, Y, Zr, Nb
Melgund Stock	Quartz Diorite	22-27 {76-98}	60-61	55-56	0.81- 0.82	0.52- 0.53	5X	11	50X	0.94-0.97	High Mg#, Ca, Mn, Ni, Cr, V, Co
Picture Island Stock	Granodiorite/ Granite	4-10 {0}	68-72	38-41	0.99- 1.03	0.21- 0.33	4-5X	16-37	70-130X	0.79-0.91	Low Na, P, Ba, Zr, Nb, Th Low Ca, Mg#, Na, Al, Ba, Sr High U, Th, Ta



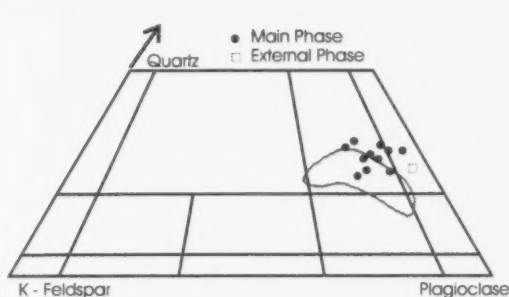
Pukaskwa Batholith



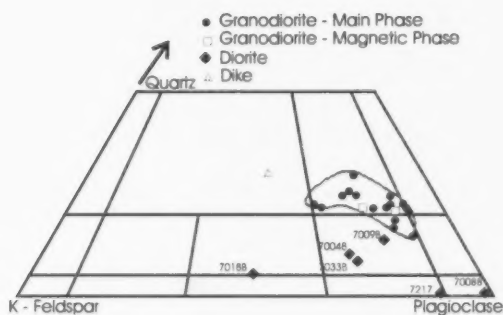
Gowan Lake Pluton



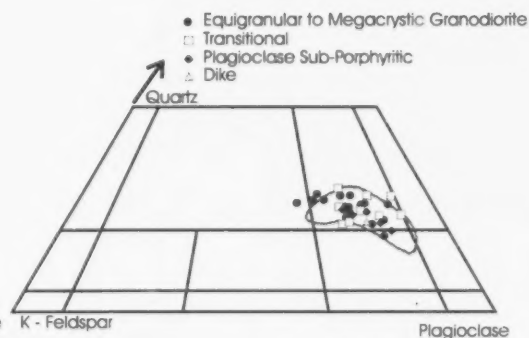
Black-Pic Batholith



Dotted Lake Batholith

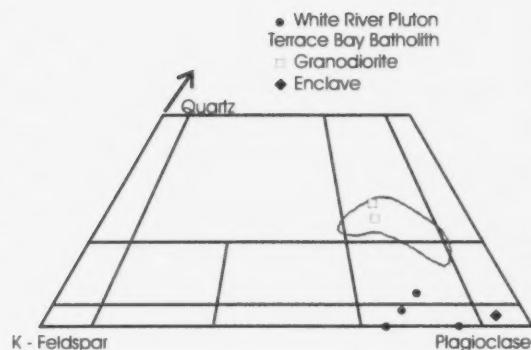


Cedar Lake Pluton

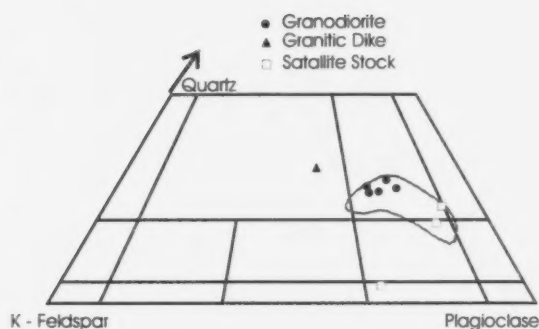


Heron Bay Pluton

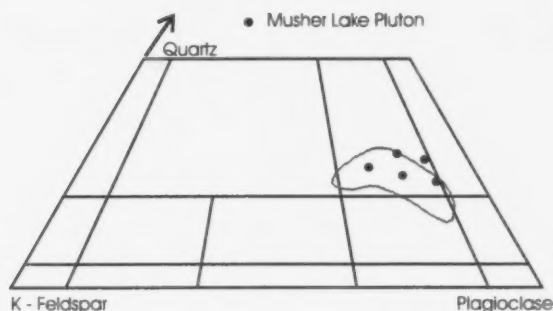
Figure 3a. Quartz - K-feldspar - plagioclase ternary diagrams for medium and coarse-grained felsic and intermediate intrusive rocks. The fields indicated are from Streikeisen (1976). The field delineating the composition of granodioritic rocks from the Cedar lake pluton is plotted on all diagrams in order to facilitate comparison.



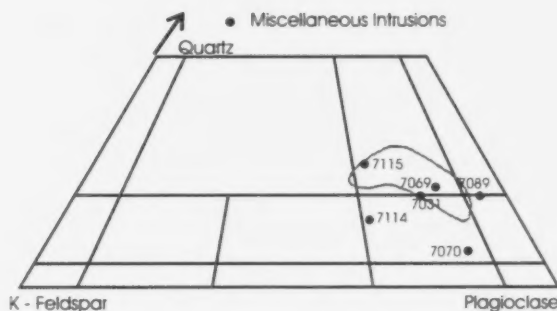
Terrace Bay Batholith
White River Pluton



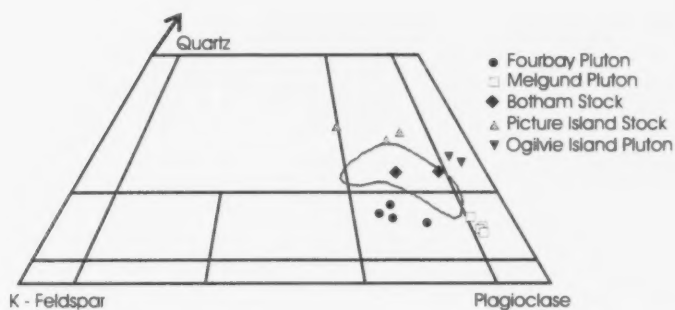
Cedar Creek Stock



Musher Lake Pluton



Miscellaneous Intrusions



Miscellaneous Plutons

Figure 3b. Quartz – K-feldspar – plagioclase ternary diagrams for medium and coarse-grained felsic and intermediate intrusive rocks. The fields indicated are from Streikeisen (1976). The field delineating the composition of granodioritic rocks from the Cedar lake pluton is plotted on all diagrams in order to facilitate comparison.

both batholiths although the mafic mineralogy differs somewhat (Figure 4). In this and subsequent discussion, the ratio of hornblende to hornblende + biotite + chlorite (H/HBC) is used as a measure of the proportion of the hornblende in the original mafic mineralogy (chlorite being an alteration product of biotite). The Black-Pic batholith gneissic phases are mostly biotite-dominated (H/HBC mostly < 15) whereas those of the Pukaskwa batholith range from biotite-dominated to amphibole-dominated. Epidote, sphene, opaque oxides and apatite are widespread accessory minerals. Traces of zircon and sulphide are present in some samples.

Some of the massive to foliated phases of the Pukaskwa and Black-Pic batholiths are mineralogically similar to the gneissic phases although they exhibit a greater tendency to be hornblende-dominated. Those of the Pukaskwa batholith tend to be slightly more quartz-rich than gneissic phases whereas those of the Black-Pic batholith have comparable or significantly lower quartz abundances. The quartz-poor phases of the Black-Pic batholith are also geochemically distinct as discussed below and may be related to younger magmatic activity discussed in a subsequent section.

Petrology and Mineralogy of Main Phases

Biotite dominates the mafic mineralogy of the Black-Pic batholith foliated to gneissic phases (H/HBC= 0 to 0.14; Figure 4) with only one sample from an area east of the Dotted Lake batholith being anomalously biotite-poor and hornblende-rich (H/HBC= 0.97). In contrast, the foliated to gneissic phases of the Pukaskwa batholith are characterized by either biotite (H/HBC= 0) or hornblende subequal to biotite (H/HBC= 0.33 to 0.84). Plagioclase feldspar exhibits weak to moderate patchy alteration to a fine-grained aggregate of white mica, epidote and carbonate. The extent of chloritization of biotite is highly variable, ranging to negligible to complete. Common, relatively abundant, accessory minerals include epidote, sphene and opaque oxide whereas apatite is a common trace accessory phase. Traces of zircon and sulphide are present in some samples.

These rocks generally preserve aspects of a primary hypidiomorphic equigranular to plagioclase porphyritic magmatic texture but these are modified by recrystallization associated with fabric development. The principal fabric elements that modify the magmatic textures include orientation of biotite, hornblende and mafic crystal aggregates and, less commonly, flattened, recrystallized quartz grains.

Quartz occurs as equant to oblate, optically continuous to polysutured grains. Plagioclase is typically subhedral with weak, patchy alteration and limited compositional zoning. Plagioclase composition is generally fairly uniform within individual samples, even when plagioclase from leuco-tonalitic lenses are compared with that of the host, more melanocratic tonalite, but analyses for different samples range from averages of approximately An₂₈ to An₄₁. In some cases, plagioclase is somewhat coarser (<1 cm), imparting a porphyritic texture to otherwise equigranular rocks. K-feldspar (generally > Or₉₄) typically occurs as discrete, smaller, interstitial grains. Hornblende (edenite and hastingsite in two samples for which microprobe analyses are available) occurs as fresh,

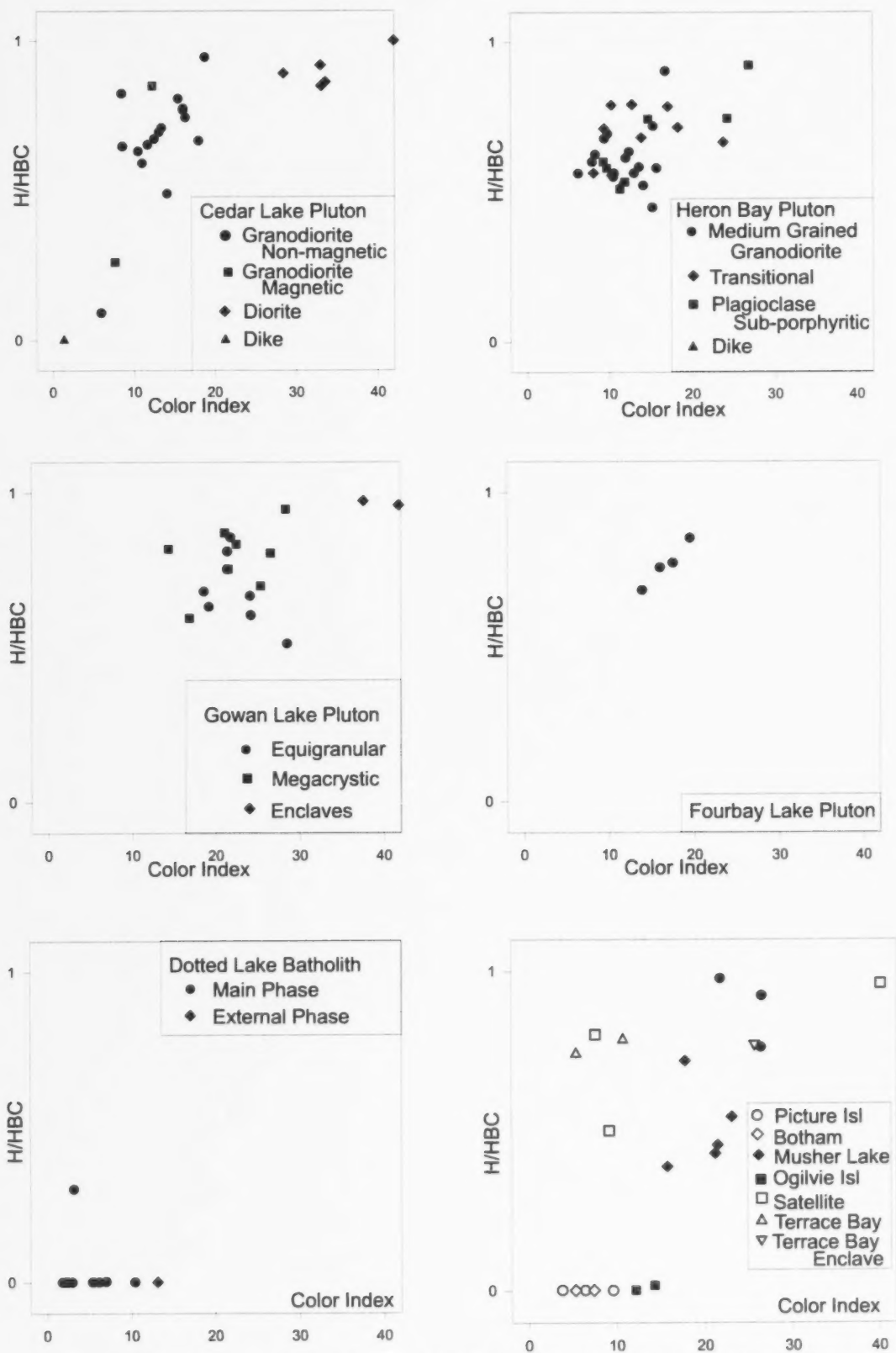


Figure 4. Color index vs H/HBC (hornblende/hornblende + biotite + chlorite) for medium to coarse grained felsic and intermediate intrusive rocks.

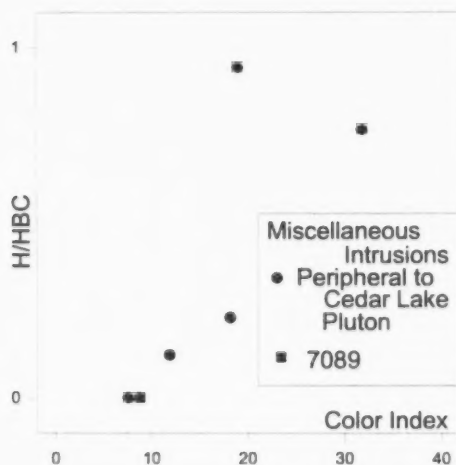
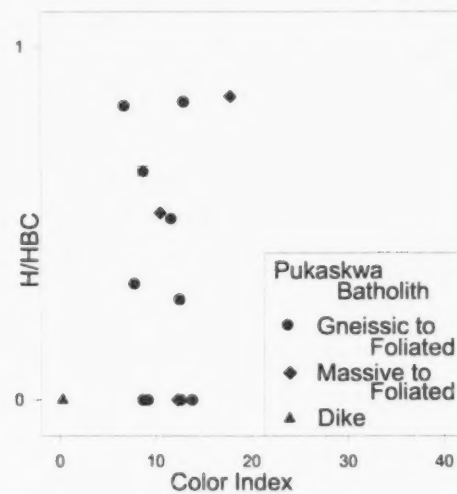
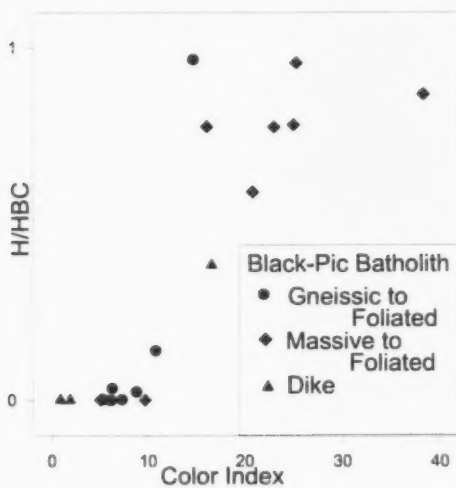
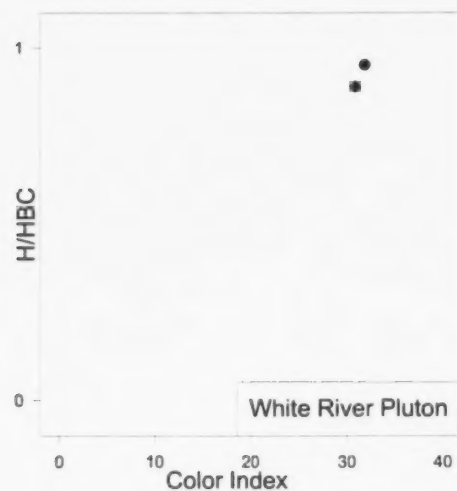
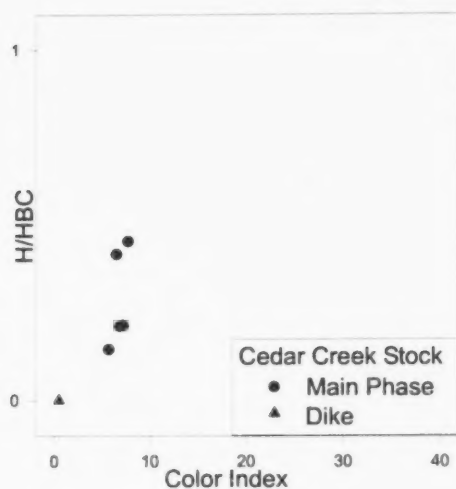


Figure 4 (continued). Color index vs H/HBC (hornblende/hornblende + biotite + chlorite) for medium to coarse grained felsic and intermediate intrusive rocks.

subhedral to euhedral crystals whereas biotite is variously altered to chlorite and occurs both as discrete individual grains and as part of crystal aggregates. Epidote occurs both as discrete, larger (< 1 mm), subhedral to euhedral grains that rarely display simple twinning and fine grained alteration product of plagioclase. The former variety is commonly associated with mafic crystal aggregates and is interpreted to be of magmatic origin. Sphene occurs as subhedral to euhedral crystals that are in some cases associated with Ti-bearing oxide phases. Apatite and zircon occur as euhedral crystals in a wide variety of phases. Where oxide phases are abundant, they occur primarily as simple, subhedral to euhedral octahedra. Other modes of occurrence of oxide phases include replacement of sphene and as platy grains within biotite. In both of these cases, lamellar exsolution textures involving a Ti-rich and Ti-poor oxide phases are common.

Foliated to massive phases partially overlap the QFP compositional field of the foliated to gneissic phases but differ in several respects (Figure 3). Massive to foliated phases in the Pukaskwa batholith may be slightly more quartz-rich than the foliated to gneissic phases but have comparable mafic mineralogy. The massive to foliated phases of the Black-Pic batholith are more compositionally variable (granodiorite – quartz monzodiorite – monzodiorite) (Figure 3) and range from relatively leucocratic, biotitic varieties to more melanocratic, hornblende-dominated varieties (Figure 4). The more leucocratic, tonalitic massive to foliated phases do not differ appreciably in any aspect of their mineralogy from the foliated to gneissic phases and may be related. The more mafic monzodioritic to quartz monzodioritic phases within the Black-Pic batholith are also distinguished from the foliated to gneissic tonalites by:

- 1) slightly to notably plagioclase and/or hornblende porphyritic character
- 2) plagioclase may be somewhat more altered
- 3) minor clinopyroxene cores are present in some amphiboles
- 4) less abundant oxide phase occurring primarily as platy grains
- 5) magmatic epidote crystals with radiation damaged (allanite?) cores

These massive, more mafic phases of the Black-Pic batholith are similar in many respects to the Gowan Lake and Fourbay Lake plutons discussed below.

Dike phases display considerable diversity and no attempt was made to analyze all varieties. The most common varieties have leucogranitic compositions and medium grained, equigranular to coarsely pegmatitic textures. The leucogranitic dikes are also characterized by biotite, which is generally intensely chloritized, and intense plagioclase alteration. The only other type of dike analyzed in detail is a hornblende-biotite quartz monzodiorite which, other than a notable abundance of sulphide, is closely comparable in terms of its mineralogy to the foliated to massive quartz monzodiorite discussed above.

Geochemical Characteristics

The gneissic to foliated granodioritic to tonalitic and a subset of the massive to foliated rocks occurring within the Black-Pic and Pukaskwa batholiths have distinctive geochemical characteristics that contrast with those of the other intermediate to felsic intrusive rocks of the Hemlo greenstone belt area. These characteristics include

relatively high SiO_2 and $\text{Na}_2\text{O}/\text{K}_2\text{O}$ and relatively lower K_2O , Mg number, Rb, Sr, Ba, Zr, Y, Ni, Cr and V (Table 3). Four tonalite samples, two from either bounding batholith, have ϵ_{Nd} between +2.9 and +3.2. The foliated to gneissic phases of the Black-Pic and Pukaskwa batholiths have comparable major element characteristics although the Pukaskwa batholith tends to have somewhat higher $\text{K}_2\text{O}/\text{Na}_2\text{O}$ ratio as well as greater abundances of Nb, Ta, Y and Yb (Figure 5). Although these rocks exhibit some broad similarities in their REE patterns they can be further subdivided into subsets that have more restricted REE characteristics (Figures 6 and 7). A geographically restricted (near contact with Hemlo greenstone belt) subset (type 1) of gneissic (7146, 7147B, 7148) and foliated (7149) samples from the Black-Pic batholith are characterized by extreme depletion of HREE with resultant very high degree of REE fractionation. Another group of samples (type 2) from the Black-Pic batholith (7170, 7209, 7213, 7315) is closely comparable to many of the foliated to gneissic samples from the Pukaskwa batholith (7141, 7273, 7281) although the latter are slightly more LREE enriched. Other samples (type 3) from both the Black-Pic (7053) and Pukaskwa (7254 and 7255) batholiths exhibit fractionation comparable to that of type 2 samples but have higher REE abundances. The magnitude of weak positive Eu anomalies correlates inversely with REE abundance with both types 1 and 2 exhibiting weak positive Eu anomalies whereas type 3 has either no or negligible weak negative anomalies. The fanning REE patterns exhibited by types 1 and 2 suggests that differential garnet or amphibole fractionation (either during crystallization or partial melting) may provide an explanation of the contrasting patterns.

Some of the massive to foliated phases occurring in the belt-bounding batholiths have the geochemical characteristics similar to those described above for the foliated to gneissic phases. With the exception of sample 7049, which as discussed above is similar to type 1 foliated to gneissic phases, massive to foliated samples from the Black-Pic batholith are less siliceous and more magnesian and are characterized by relatively higher LILE and REE than the foliated to gneissic phases. These rocks are similar in many respects to some of the lower SiO_2 massive plutons (e.g., Gowan Lake pluton) in terms of their mineralogy and geochemistry and are likely closely related and have similar origin. Two of three massive to foliated samples from the Pukaskwa batholith are comparable to foliated to gneissic phases while sample 7291 exhibits similarities with the more magnesian massive to foliated phases from the Black-Pic batholith.

One sample (7253) was selected from a thin unit within the greenstone belt at Molson Lake, approximately 4 kilometers southeast of the Hemlo gold deposit in order to test its possible affinity to the Pukaskwa batholith. This sample was found to be virtually identical in terms of its mineralogy and geochemical characteristics to sample 7144 and similar to sample 7256. Both of these latter samples are from the immediate contact area and the similarity suggests that this unit may be related to the Pukaskwa batholith. This unit, which occurs approximately 300 meters north of the greenstone belt contact (Muir, 1995), is highly tectonized and may represent either a tectonic sliver or a dike. The probable co-genetic relationship between this thin unit and the Pukaskwa batholith would allow that, should either of these two possibilities be ruled out (by field relationships

Symbol legend - Figure 5

Black-Pic Batholith	Pukaskwa Batholith	
●	○	Foliated to Gneissic Phases
◐		Foliated to Gneissic Phases (altered)
	▽	Foliated to Gneissic Phase (within margin of greenstone belt)
■	□	Massive to Foliated Phases
◆	◇	Late Granitic Dikes
	△	Feldspar Porphyry dike
▲		Gabbro
◆		Lamprophyre Dike
◆		Dioritic Dike
+		Mafic Dike
×		Amphibolitic Mafic Metavolcanic Inclusion

Figure 5. Harker variation diagrams for the Black-Pic and Pukaskwa batholiths.

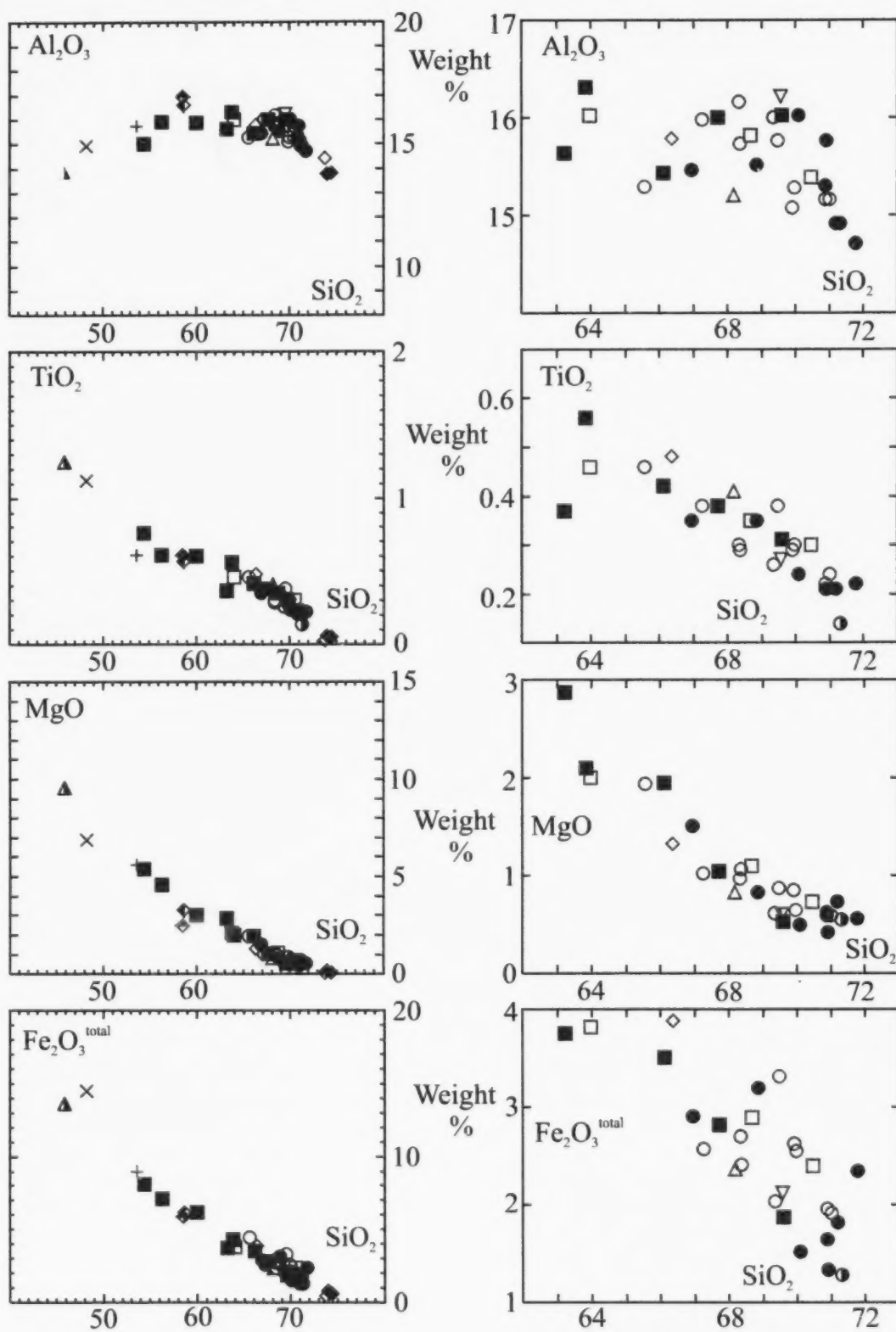


Figure 5. Harker variation diagrams for the Black-Pic and Pukaskwa batholiths.

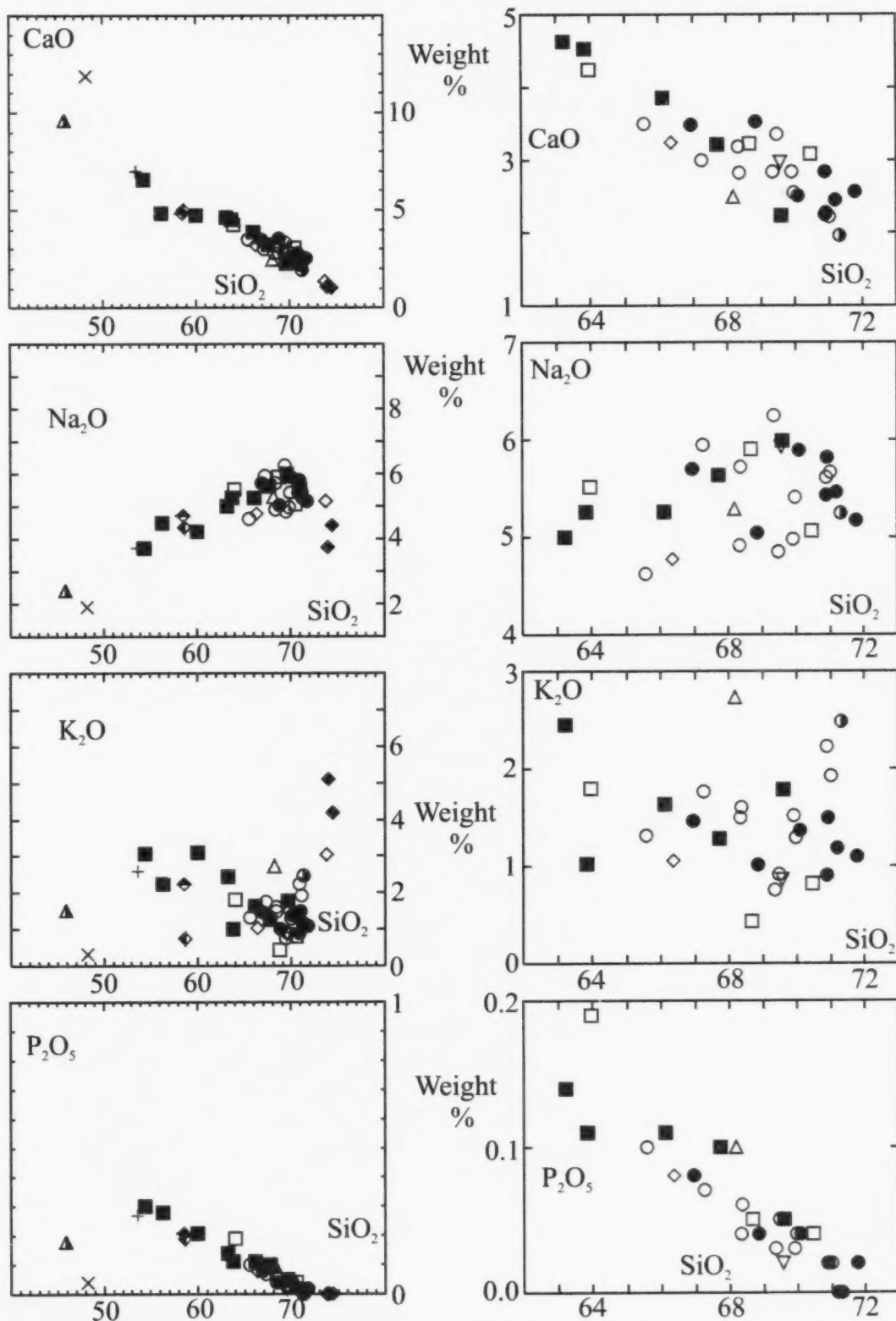


Figure 5. Harker variation diagrams for the Black-Pic and Pukaskwa batholiths.

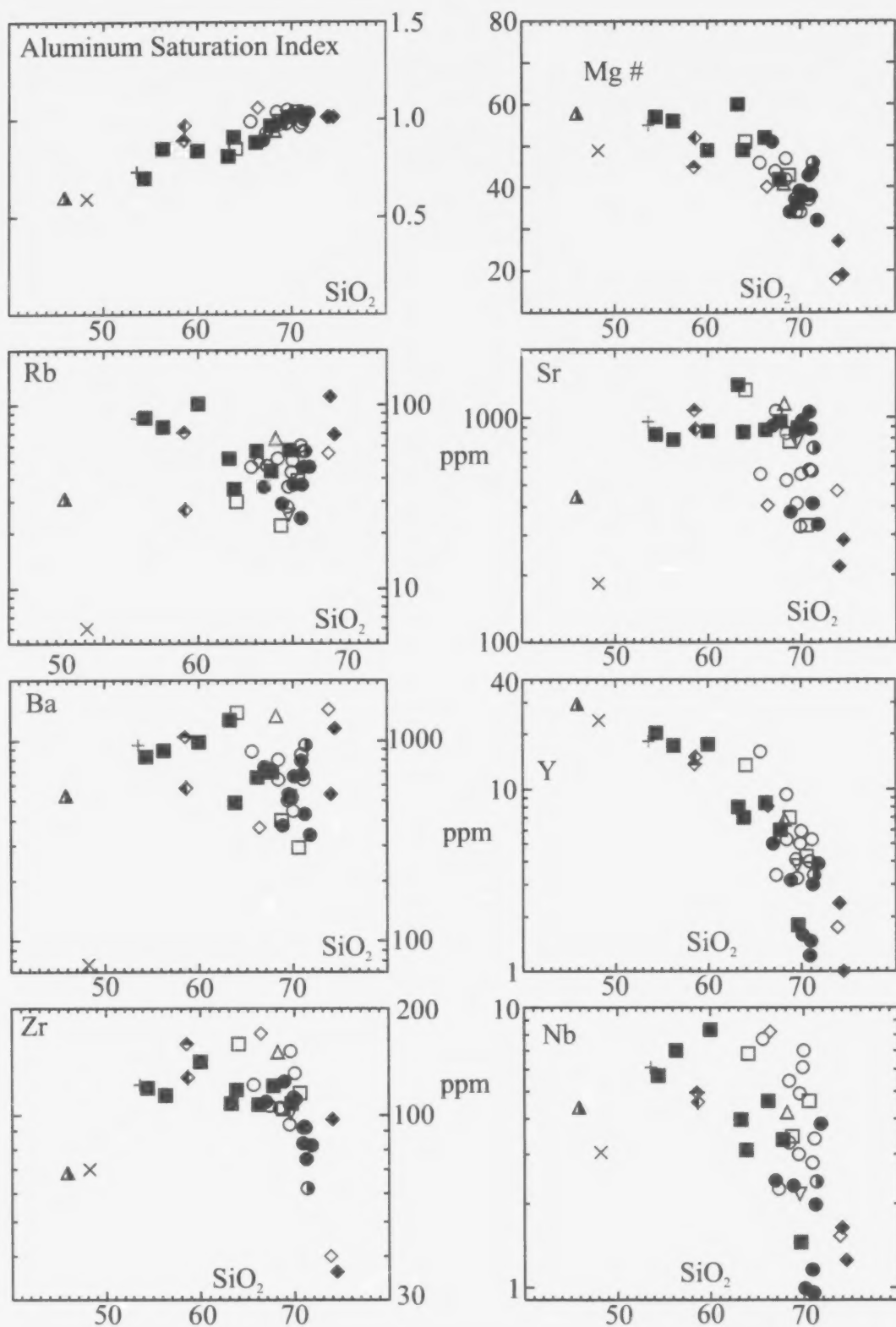


Figure 5. Harker variation diagrams for the Black-Pic and Pukaskwa batholiths.

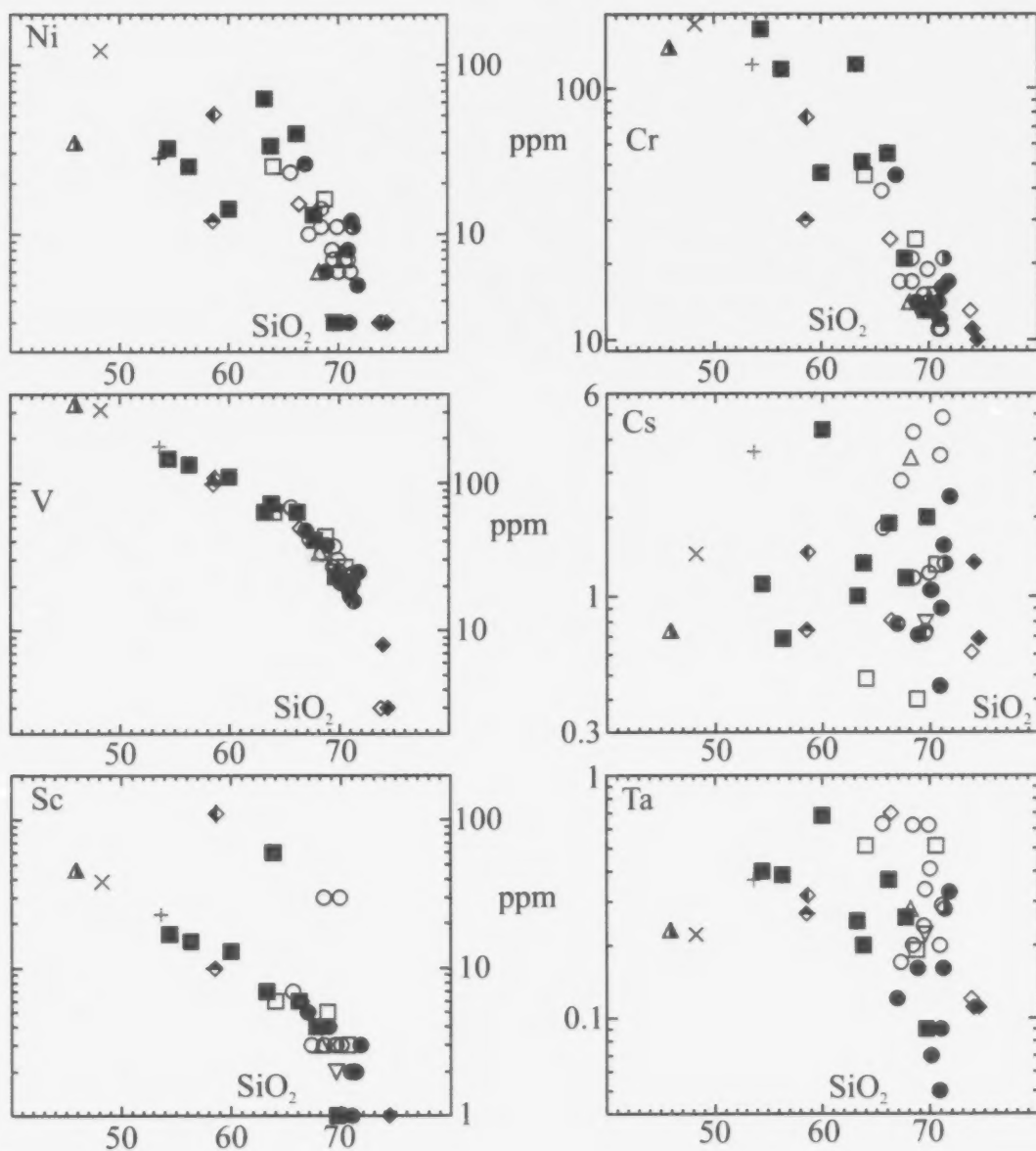


Figure 5. Harker variation diagrams for the Black-Pic and Pukaskwa batholiths.

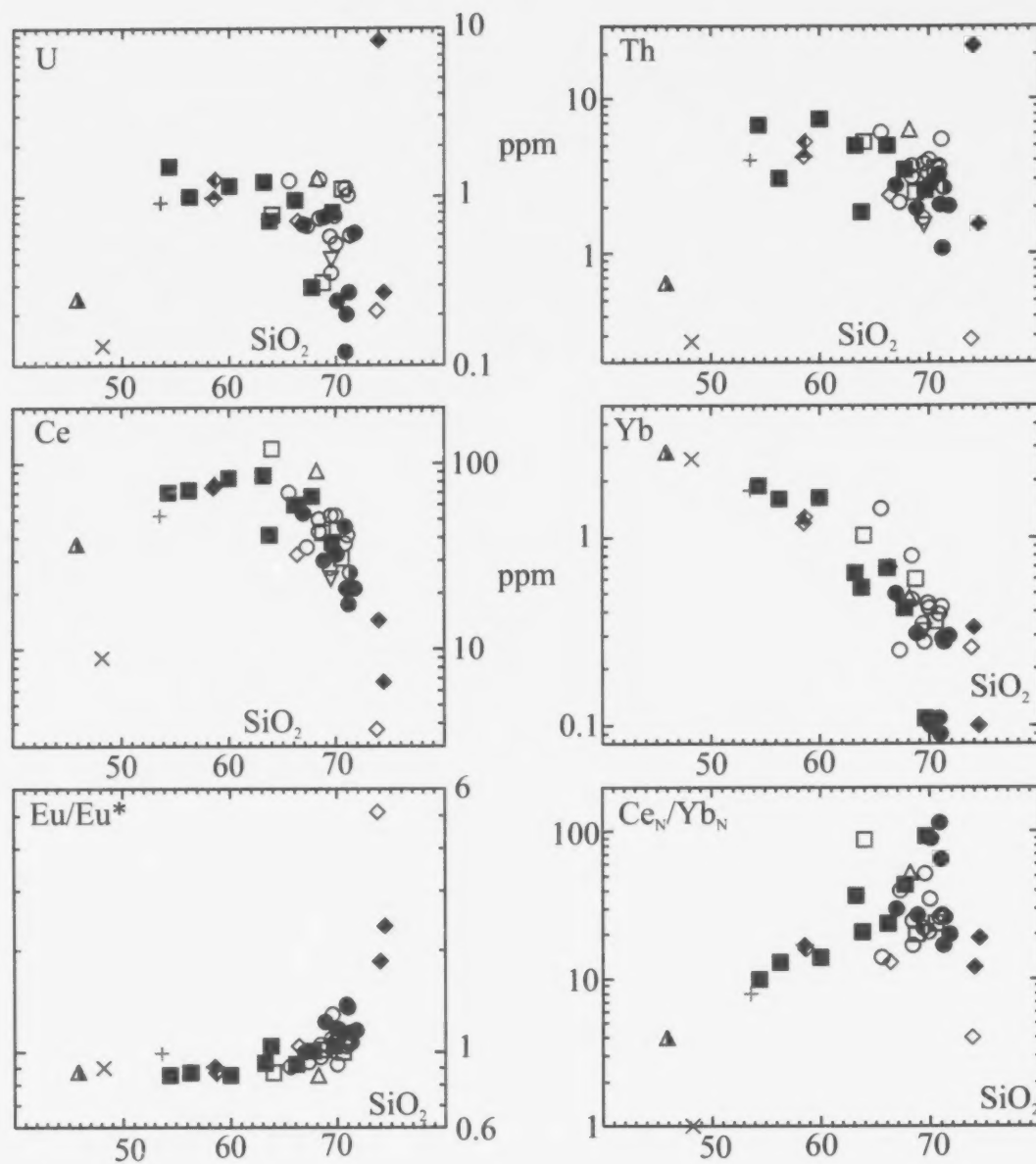


Figure 5. Harker variation diagrams for the Black-Pic and Pukaskwa batholiths.

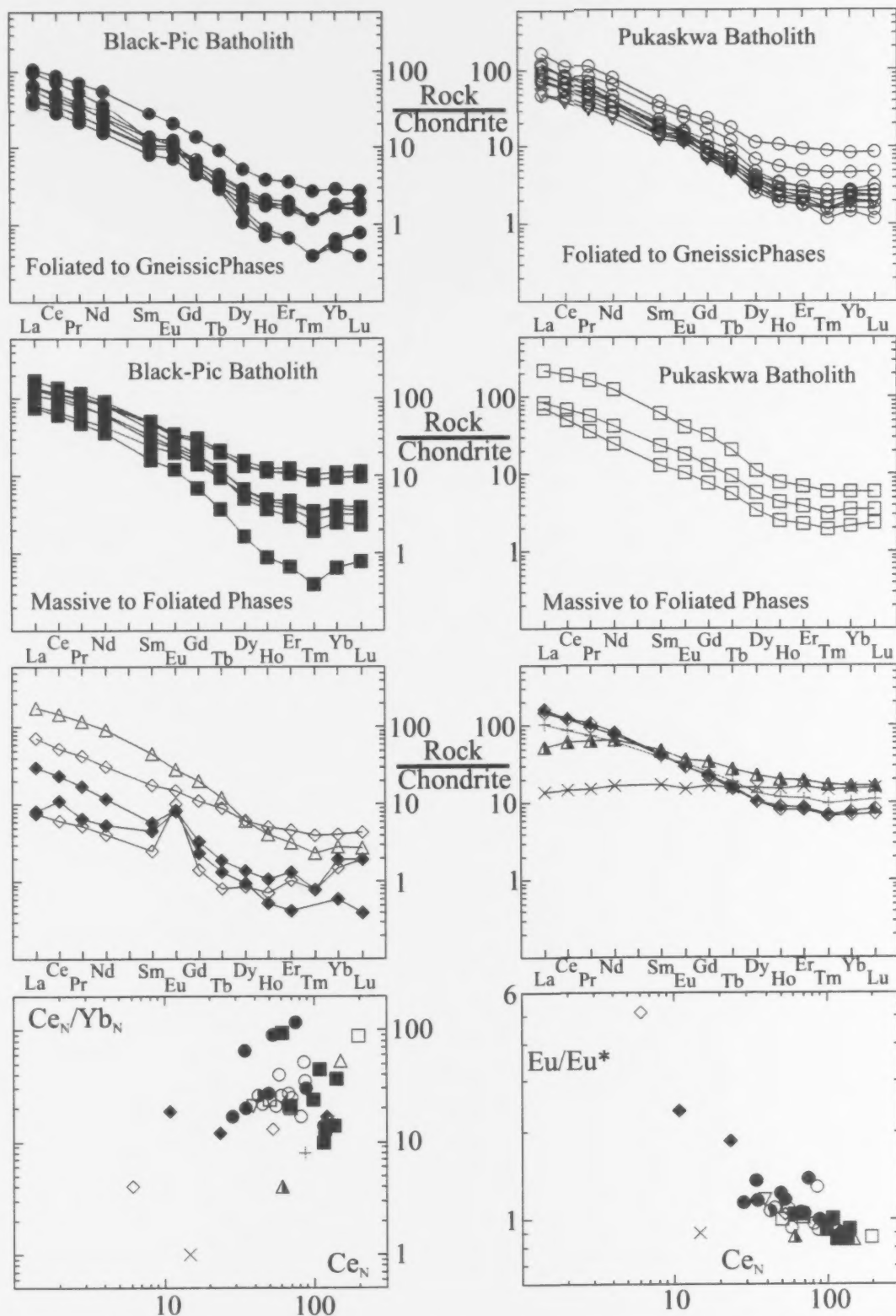


Figure 6. Chondrite normalized rare earth element data for samples from the Black-Pic and Pukaskwa batholiths. Normalization values from Sun and McDonough (1989).

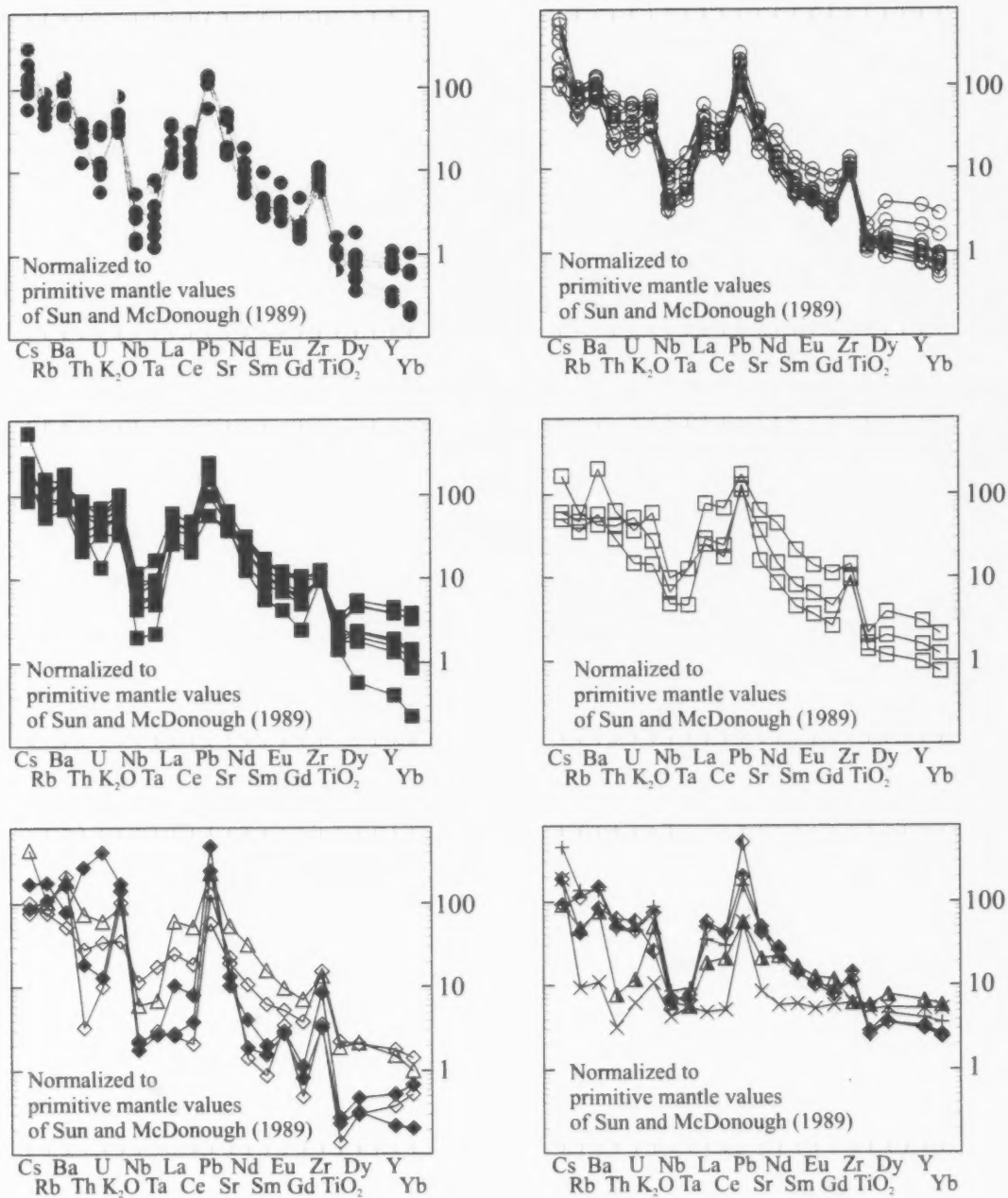


Figure 7. Primitive mantle normalized multi-element diagram for samples from the Black-Pic and Pukaskwa batholiths. Normalization values are from Sun and McDonough (1989).

and/or geochronology), the question of whether the greenstone belt margin in this area is an intrusive or tectonic contact could be resolved.

A wide variety of variously deformed, mafic to felsic minor intrusions and dikes occur in both the Black-Pic and Pukaskwa batholith and, in general, they have diverse characteristics and origin. Geochemical characteristics and petrogenetic interpretations are summarized (Table 4) for the small number of minor intrusions examined.

Petrogenetic Interpretation of Tonalitic Rocks within Belt-bounding Batholiths

Depleted mantle Nd isotopic signatures ($\epsilon_{Nd} = +2.9$ to $+3.2$) as well as lack of evidence for older inherited zircons indicate that there is unlikely to be significant involvement of significantly older crustal rocks in the generation of the tonalitic component of the Black-Pic and Pukaskwa batholiths. Furthermore, observed negligible or weakly positive Eu anomalies as well as variable, but generally high, Sr abundance is inconsistent with melting of crustal rocks where significant amounts of plagioclase would be expected in the residue which would result in depletion of Eu and Sr in the melt. Metasedimentary crustal sources in particular are unlikely in view of the metaluminous to weakly peraluminous character of the tonalites.

The foliated to gneissic, tonalitic to granodioritic phases (particularly types 1 and 2 above), as well as a subset of the massive to foliated phases, of the belt-bounding batholiths share many characteristics with Archean, high-Al TTG suite plutons that are commonly interpreted to originate by partial melting of basaltic crust (e.g., Martin, 1987; Drummond and Defant, 1990). Notable similarities include high Na/K, Sr, Al_2O_3 and low Rb, Y and HREE. Depleted mantle-type Nd isotopic signatures are also typical of TTG suite magmas. The moderate to high degrees of REE fractionation and extreme HREE depletion requires that garnet would be a significant residual component. Attempts to model the degree of HREE depletion observed with amphibole-bearing assemblages and any reasonable basaltic source composition were unsuccessful. The most successful models for achieving the observed degrees of HREE depletion, as well as weak positive Eu anomalies, were those with an eclogitic residue (Figure 8). The degree of REE fractionation observed is somewhat greater than that typically observed in TTG suite rocks and reasonable matches of predicted melt compositions and observed compositions were only achieved with slightly LREE-enriched basaltic source compositions. Such patterns for basaltic rocks are widely observed but not abundant in Superior Province greenstone belts. Type 3 tonalites are not readily reconciled with this model unless the basaltic source rock is exceptionally enriched in all REE. The higher Mg#, Ni and Cr displayed by these samples might indicate an affinity with younger plutons having sanukitoid affinity (discussed below).

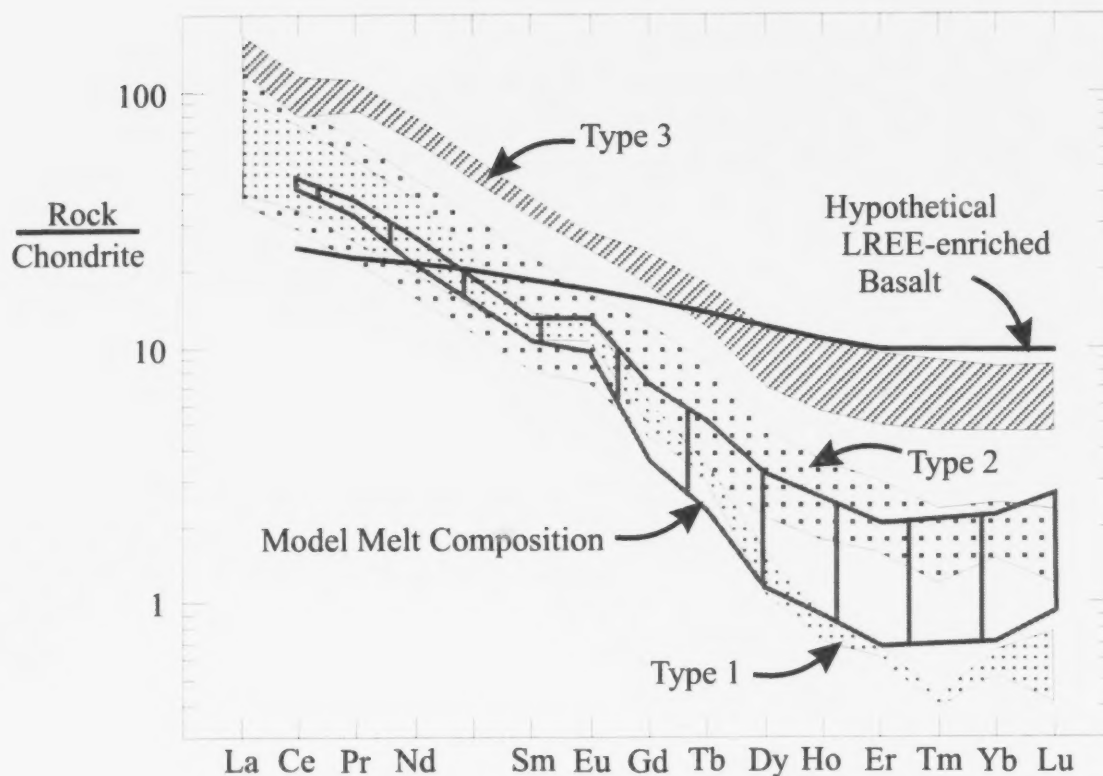


Figure 8. Chondrite normalized rare earth element patterns for foliated to gneissic tonalitic to granodioritic rocks from the Black-Pic and Pukaskwa batholiths compared to that predicted for partial melting of a hypothetical tholeiitic basalt leaving an eclogitic residue. The model melt compositional range is calculated from partition coefficient data summarized by Arth (1976) and utilizing equations for equilibrium, non-modal batch melting (Shaw, 1970). The model melt range indicated is reflective of a range of melt percentages from 5 to 25% with eclogitic residual assemblages. The putative source basalt composition is required to be moderately fractionated in order to explain the observed REE fractionation in the tonalites.

Table 4. Summary of geochemical characteristics and petrogenetic interpretations of minor intrusions from the Black-Pic (BPB) and Pukaskwa (PB) batholiths.

Sample	Setting	Distinctive Major Element Characteristics	Distinctive Trace Element Characteristics	REE	Interpretations
7147	Mafic volcanic inclusion in gneissic tonalite- BPB	SiO ₂ =48% TiO ₂ =1.1% K ₂ O=0.3% Na ₂ O=1.9% Mg#=49	Rb=6 ppm Sr=182 ppm Zr=70 ppm Ni=122ppm Th=27 ppm	Ce _N /Yb _N =1 Yb _N =15 Ce _N =15 Eu/Eu* = 0.9	Sub-alkaline, tholeiitic basalt
7317B	Mafic dike cutting foliated to gneissic tonalite- BPB	SiO ₂ =53% TiO ₂ =0.6% K ₂ O=2.6% Na ₂ O=3.7% Mg#=55	Rb=85 ppm Sr=953ppm Zr=122 ppm Ni=28 ppm Th=4 ppm	Ce _N /Yb _N =8 Yb _N =10 Ce _N =86 Eu/Eu* = 0.99	High-K, calc-alkaline basalt derived from enriched mantle source
7147C	Deformed leucogranitic dike that cross-cuts gneissosity - BPB	SiO ₂ =74% TiO ₂ =0.05% K ₂ O=4.2% Na ₂ O=4.4% Mg#=19	Rb=69 ppm Sr=285ppm Zr=36 ppm Ni=<5 ppm Th=1.6 ppm Th/U=5.7	Ce _N /Yb _N =19 Yb _N =0.6 Ce _N =11 Eu/Eu* = 2.4	Granitic melts or supercritical fluids originating either by fractional crystallization or partial melting of tonalite. Depletion of trivalent REE due to extraction of late fluid phase.
7315B	Leucogranite cutting gneissic tonalite - BPB	SiO ₂ =74% TiO ₂ =0.06% K ₂ O=5.1% Na ₂ O=3.75% Mg#=27	Rb=111ppm Sr=218ppm Zr=97 ppm Ni=<5 ppm Th=22.6 ppm Th/U=2.7	Ce _N /Yb _N =12 Yb _N =2 Ce _N =23 Eu/Eu* = 1.9	
7276B	Leucogranite cutting gneissic tonalite - PB	SiO ₂ =74% TiO ₂ =0.03% K ₂ O=3.0% Na ₂ O=5.2% Mg#=18	Rb=55 ppm Sr=470ppm Zr=40 ppm Ni=<5 ppm Th=0.3 ppm Th/U=1.3	Ce _N /Yb _N =4 Yb _N =1.5 Ce _N =6 Eu/Eu* = 5.1	
7272	Granodiorite dike cutting amphibolite-rich zone in gneissic tonalite- PB	SiO ₂ =66% TiO ₂ =0.48% K ₂ O=1.1% Na ₂ O=4.8% Mg#=40	Rb=49 ppm Sr=403ppm Zr=170 ppm Ni=15 ppm Th=2.4 ppm	Ce _N /Yb _N =13 Yb _N =4 Ce _N =53 Eu/Eu* = 1.04	
7149B	Undeformed amphibole-phyrlic intermediate dike- BPB	SiO ₂ =59% TiO ₂ =0.61% K ₂ O=2.2% Na ₂ O=4.7% Mg#=45	Rb=69 ppm Sr=285ppm Zr=159 ppm Ni=12 ppm Th=4.3 ppm	Ce _N /Yb _N =17 Yb _N =7 Ce _N =120 Eu/Eu* = 0.91	Possibly related to massive, more magnesian phases of BPB and late massive plutons such as Gowan Lake pluton.
7209C	Lamprophyre dike- BPB	SiO ₂ =59% TiO ₂ =0.57% K ₂ O=0.8% Na ₂ O=4.4% Mg#=52	Rb=27 ppm Sr=888ppm Zr=128 ppm Ni=51 ppm Th=5.3 ppm	Ce _N /Yb _N =16 Yb _N =8 Ce _N =124 Eu/Eu* = 0.87	

Dotted Lake Suite

The sole representative of the Dotted Lake suite in the Hemlo greenstone belt area is the Dotted Lake batholith. The elevation of the Dotted Lake batholith to suite status is based on 1) the distinctive mineralogical and geochemical characteristics of the unit, 2) the (currently) unique age of the unit and 3) the possible existence of comparable units outside the immediate area of the Hemlo greenstone belt.

The Dotted Lake batholith exhibits a fairly uniform mineralogy straddling the granodiorite – tonalite field boundary (Figure 3). The biotitic character and low color index of the unit (Figure 4) are noteworthy and, together with a general paucity of inclusions or enclaves of any sort, distinguish this unit from all other major plutons in the Hemlo greenstone belt area. Other accessory and trace primary minerals include sphene, opaque oxides, epidote, apatite and zircon. Secondary minerals include chlorite (after biotite) as well as minor white mica, carbonate and sulphide.

Petrology and Mineralogy

The texture and mineralogy of the Dotted Lake batholith is extremely uniform over the large area of the batholith. Except where overprinted by intense deformational fabric development the batholith displays a coarse grained, hypidiomorphic granular texture. The texture is dominantly equigranular but quartz is locally slightly coarser grained imparting a somewhat porphyritic character to the rock. Rarely, interstitial microcline forms irregular, optically continuous masses that may represent early stages of late magmatic, megacryst development.

Plagioclase feldspar is generally subhedral and displays weak to moderately strong alteration to a fine grained mixture of white mica, epidote and carbonate. The intensity of alteration is generally non-uniform in individual grains and may be either irregular and patchy or occur as symmetrical zones of alteration. It is not clear if the latter reflects selective alteration of particular compositional zones after formation of the entire crystal or fluctuations in volatile activity accompanying growth of the crystals. Optical microscopy suggests common, weak, oscillatory zoning. Microprobe analyses of several samples indicate that plagioclase is either relatively compositionally uniform or displays weak normal zoning (e.g., $An_{28}-An_{23}$, $An_{36}-An_{24}$). Microcline occurs as smaller interstitial grains and less commonly as patchy replacement of plagioclase feldspar. As discussed above, this interstitial microcline rarely coalesces into irregular optically continuous masses. Microcline is unaltered and compositionally is greater than 95 percent Or component. Quartz occurs as large grains that have been transformed by recrystallization into polysutured quartz aggregates. Minor myrmekite occurs along the margins of microcline.

Biotite, occurring as subhedral to euhedral plates, is the dominant mafic mineral. It is commonly weakly to intensely chloritized. Very minor hornblende was observed in several thin sections but is atypical. Epidote occurs both as the fine grained alteration product of plagioclase and as coarse, euhedral to subhedral crystals that appear to be

primary magmatic crystals. Opaque minerals include minor magnetite octahedra as well as rare, small, platy Fe-Ti oxide grains along biotite cleavage planes. Other accessory minerals include sphene, apatite and zircon all of which occur as euhedral, primary grains that, along with epidote, appear to be relatively early phases based on their inclusion in biotite crystals.

Geochemical Characteristics

The geochemical characteristics of the Dotted Lake batholith (Figures 9 and 10) are also distinctive with respect to other intermediate to felsic intrusions in the Hemlo greenstone belt area. The most noteworthy major element characteristics of the unit as a whole are the high SiO_2 and low Fe_2O_3 , MgO , TiO_2 and P_2O_5 content reflecting the leucocratic nature of the unit whereas the high Na_2O and low CaO and K_2O reflect the dominance of sodic plagioclase feldspar. These rocks are further characterized by their consistently mildly peraluminous ($\text{ACNK} = 1.01\text{-}1.06$) and low Mg/Fe ($\text{Mg \#} = 36\text{-}47$) nature. Distinctive trace element characteristics include relatively low Rb, Nb, Zr, Y, U, Th, Sc, Ta, Ni, Cr, V and Co. REE (Figure 10) have low overall abundance and are mildly to moderately fractionated ($\text{Ce}_\text{N}/\text{Yb}_\text{N} = 7\text{-}22$) with near chondritic HREE and, generally, weak, positive Eu anomalies ($\text{Eu}/\text{Eu}^* = 0.91\text{-}1.43$). Nd isotopic data indicates a depleted mantle ($\epsilon_{\text{Nd}} = +2.3$) isotopic signature.

The internal geochemical variation is restricted, reflecting the uniform mineralogy and modal mineral abundance, but nevertheless, defines smooth variation trends for most elements (Figure 9). Several observations are relevant to the origin of the within unit variation. The consistency of weakly positive Eu anomalies that exhibit no well-defined covariation with CaO abundance suggests that fractional crystallization involving a significant plagioclase component cannot explain the observed within unit chemical variation. Fractionation of biotite might enrich the melt in REE but cannot explain the observed range in REE fractionation ($\text{Ce}_\text{N}/\text{Yb}_\text{N} = 7$ to 22) and would result in extreme depletion of the melt in Rb and Ba which is not observed. The crossing or fanning of REE patterns (reflected in the range of $\text{Ce}_\text{N}/\text{Yb}_\text{N}$) with the most extreme fractionation reflecting HREE depletion more so than LREE enrichment requires the involvement of a mineral phase capable of preferential removal of HREE. The most probable candidates are hornblende or garnet and it is probable that one or both of these phases were involved at some point in the petrogenesis of these rocks. Inasmuch as hornblende is rare and garnet unknown as a mineral phase in these rocks, it is more likely that these phases were involved at the melting stage. Consequently, the observed range in REE fractionation is interpreted to reflect variation in the composition of primary melts and not modification of a single initial melt composition by high level crystal fractionation processes.

One notable exception to the uniformity of mineralogical and geochemical characteristics is afforded by sample 7305 (Figure 11). This sample is from what has been portrayed as apophysis of the batholith in previous mapping (Milne, 1968) but is reinterpreted here to be a discrete intrusion that is separated from the main mass of the Dotted Lake batholith by a narrow septum of metavolcanic rock. On major element geochemical variation plots (Figure 9), sample 7305 appears to represent an extension of trends evident for the Dotted

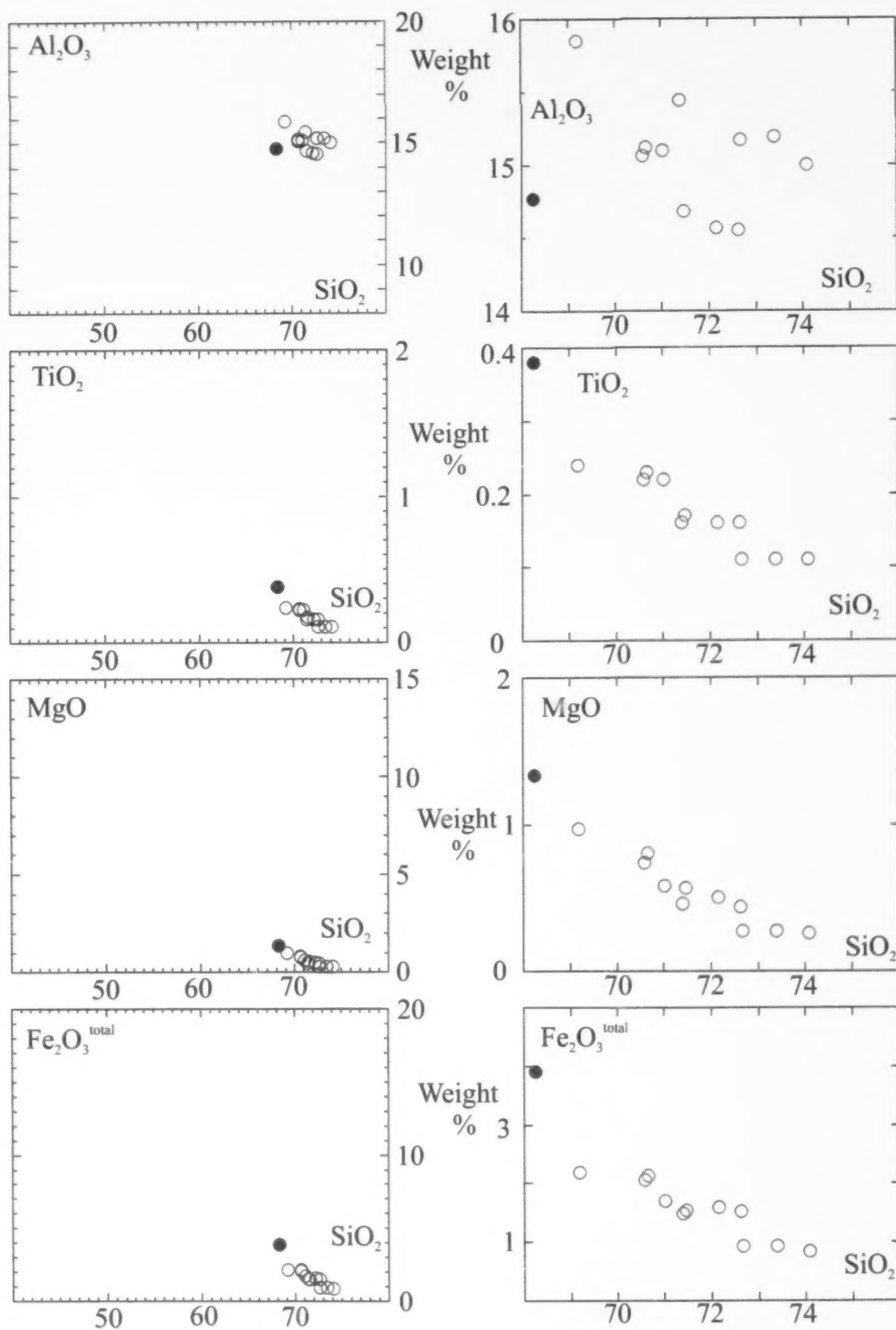


Figure 9. Harker variation diagrams for Dotted Lake batholith. Open circles= main granodiorite phase; Filled circle= sample 7305.

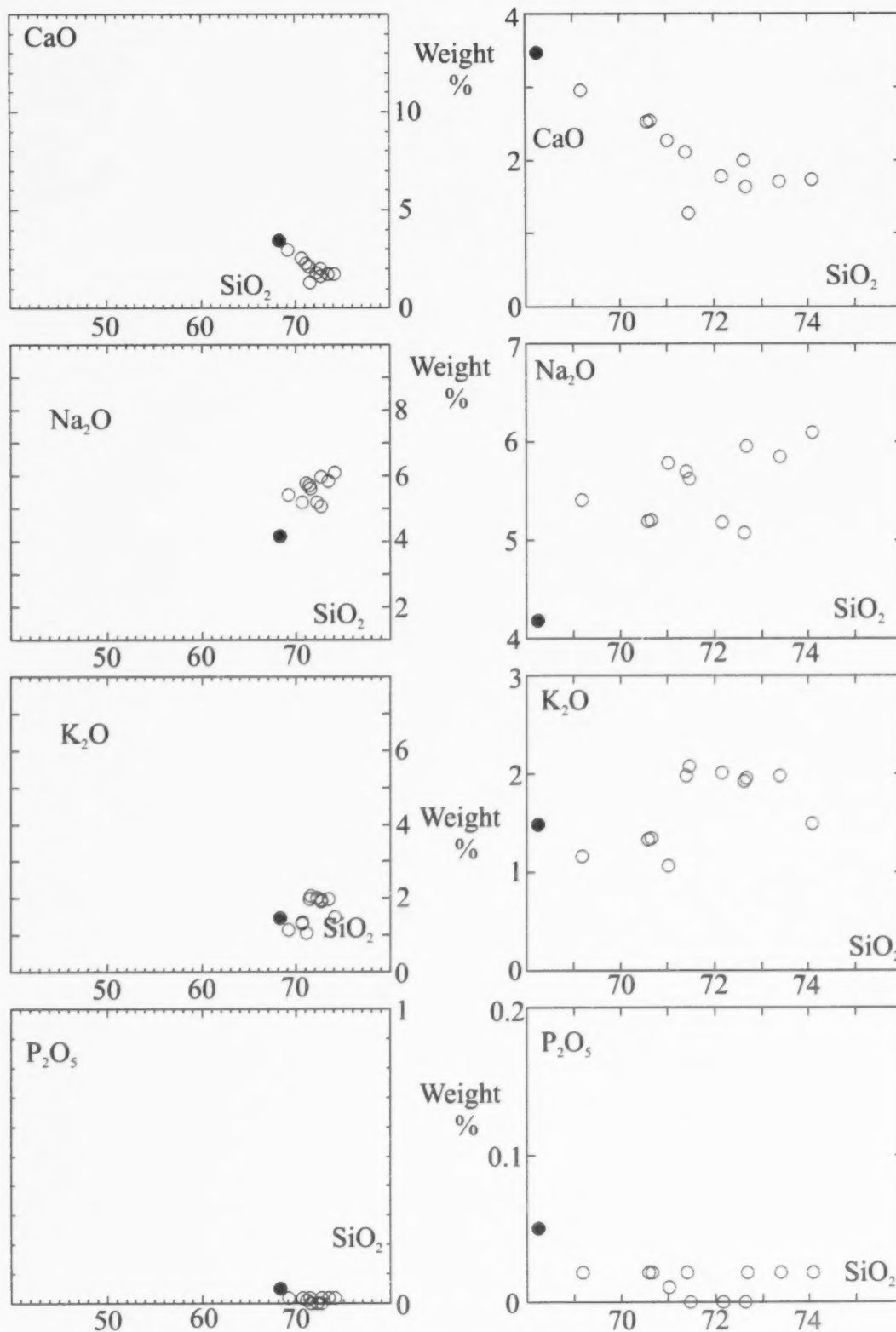


Figure 9. Harker variation diagrams for the Dotted Lake batholith

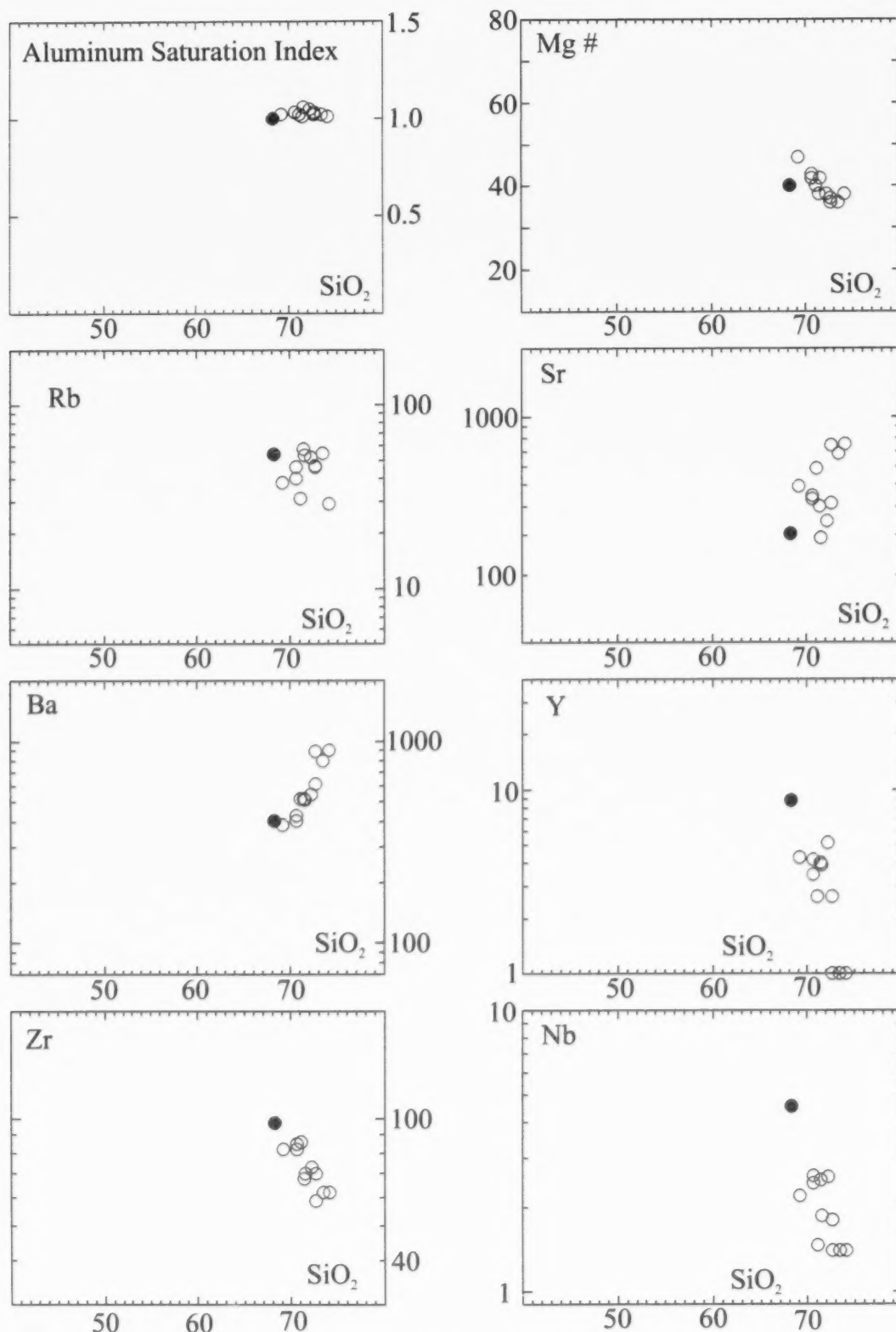


Figure 9. Harker variation diagrams for the Dotted Lake batholith.

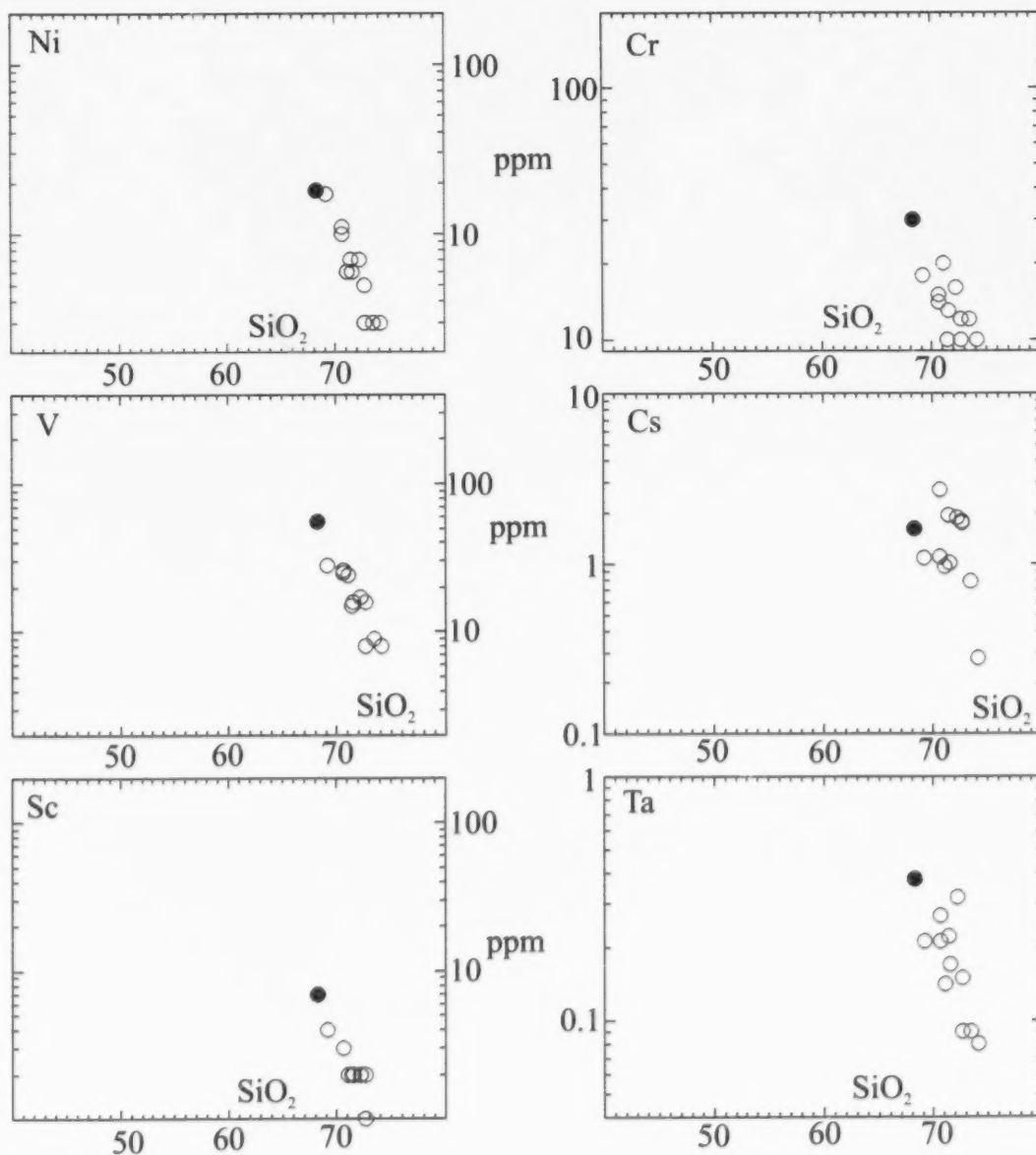


Figure 9. Harker variation diagrams for the Dotted Lake batholith.

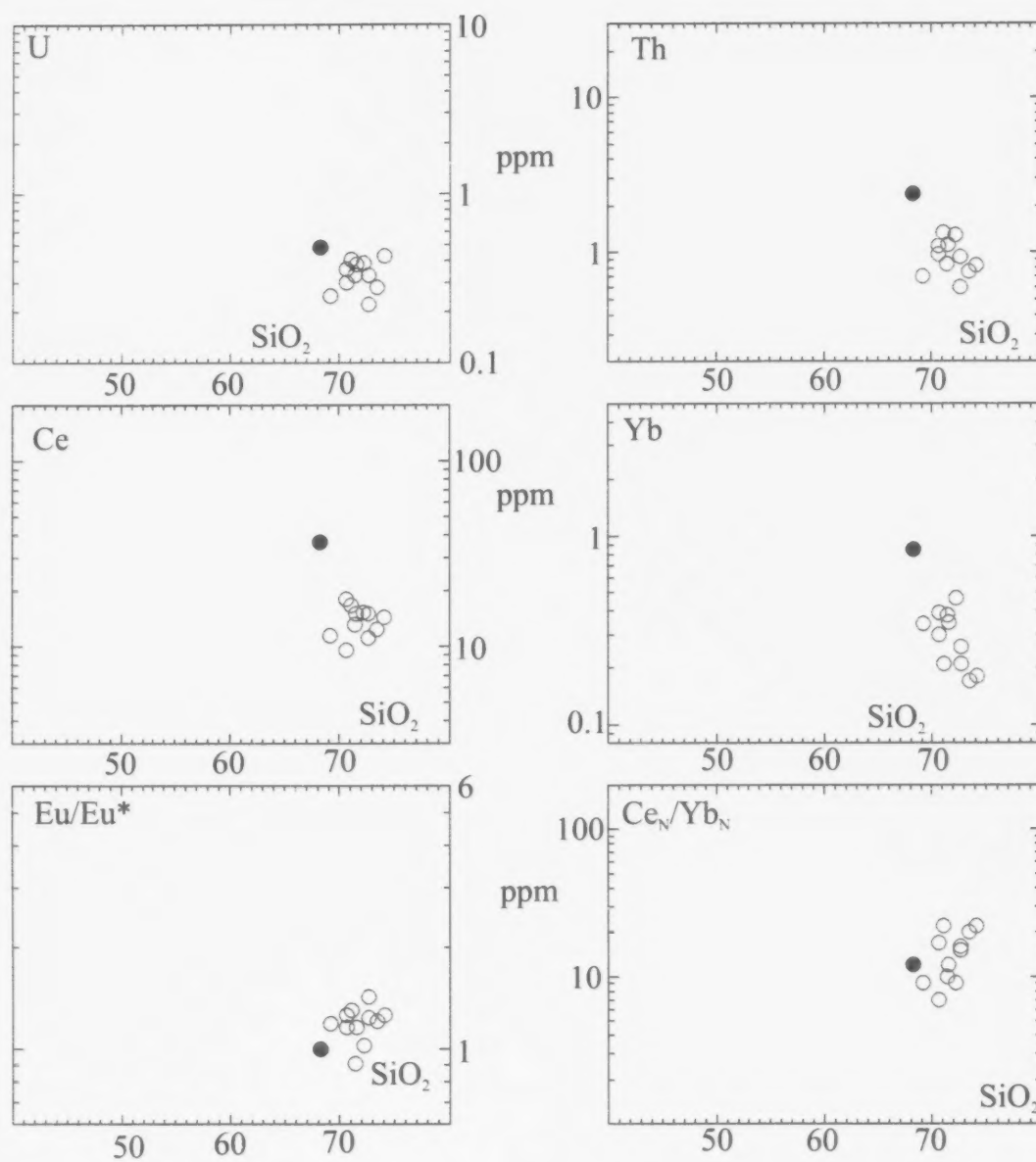


Figure 9. Harker variation diagram for the Dotted Lake batholith.

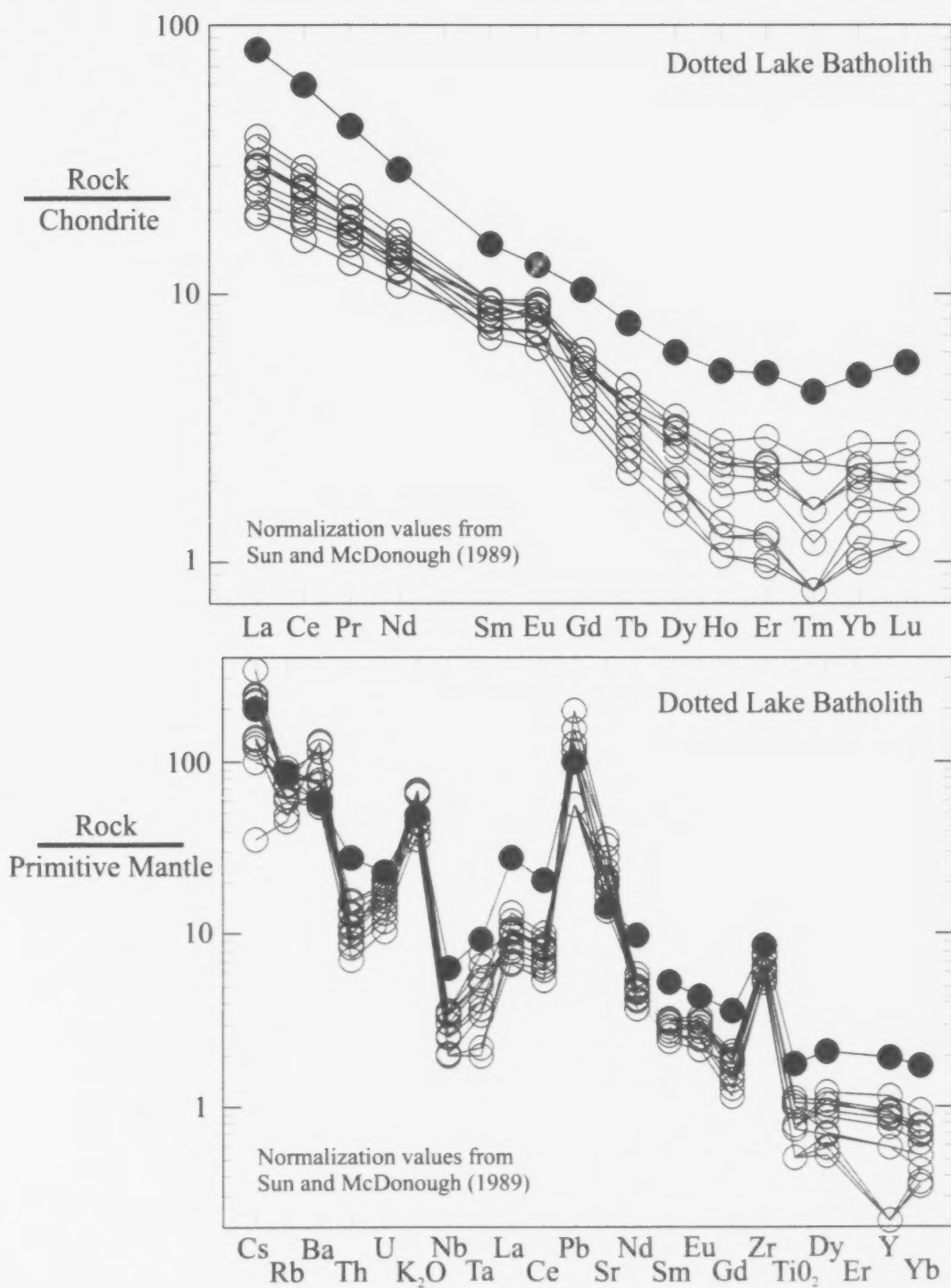


Figure 10. Chondrite and primitive mantle normalized multi-element variation diagram for the Dotted Lake batholith. Normalization values are from Sun and McDonough (1989). Open circles = main phase; closed circle = external phase.

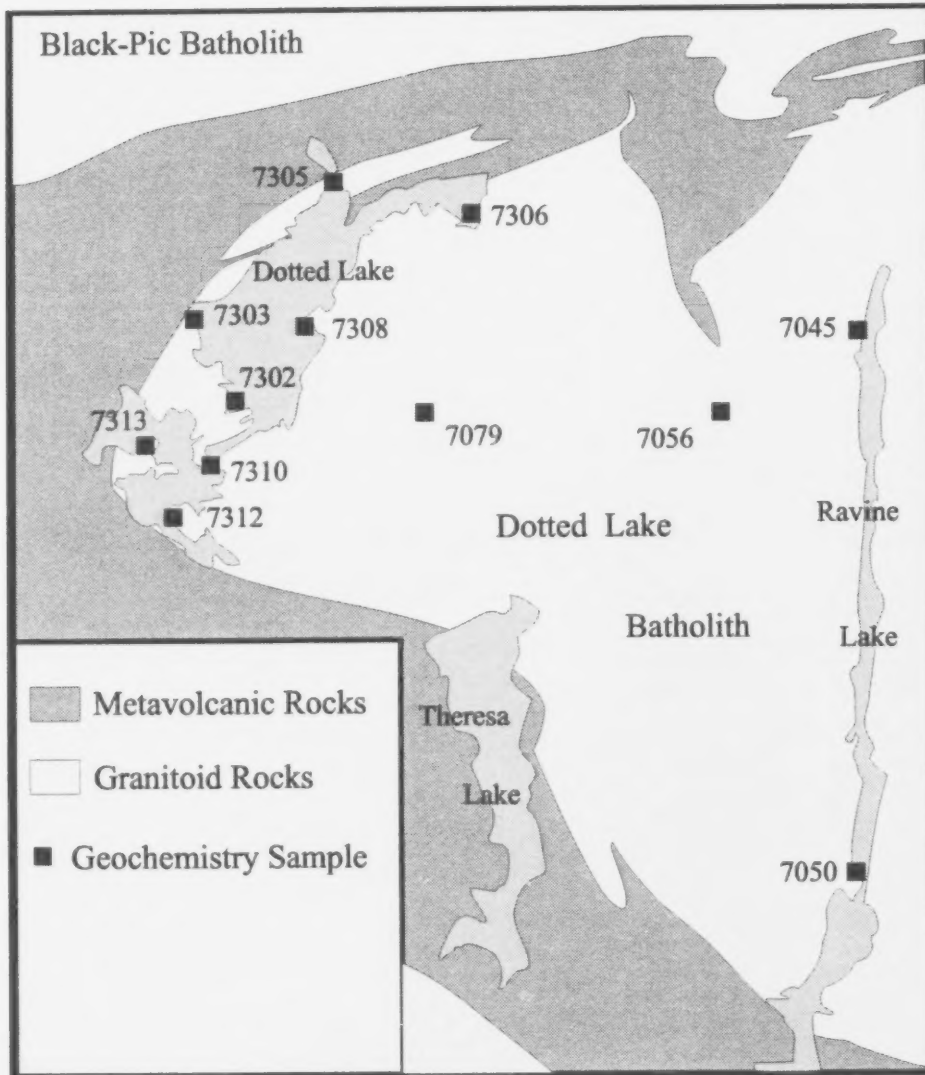


Figure 11. General geology of the vicinity of the Dotted Lake batholith with locations of geochemistry samples.

Lake batholith samples. Many trace elements display similar behavior although for some elements (Nb, Ce, Y, Yb) there is a notable gap over a narrow range in SiO_2 between 7305 and Dotted Lake samples. These relatively smooth variation trends notwithstanding, the unit is unlikely to be related to the Dotted Lake batholith for a number of reasons. Sample 7305 is more mafic and lower in SiO_2 than the Dotted Lake batholith and must be the more primitive component if this sample were related to the main batholith by some crystal fractionation process. Such fractionation would have to result in lower incompatible element abundances and weak positive Eu anomalies (Figure 10) among other geochemical characteristics. Efforts to model these trace element variations for geologically reasonable fractionating mineral phases using the equations summarized by Arth (1976) and Hanson (1978) are unsuccessful for a number of reasons. Crystallization of hornblende leads to extreme REE fractionation and HREE depletion that is not observed. Biotite fractionation enriches, not depletes REE, and results in extreme depletion of Rb and Ba that is not observed. Feldspar fractionation also enriches REE in the melt and results in development of strong negative, rather than weak positive, Eu anomalies. Consequently, all of the likely main mineral phases that could lead to fractionation result in characteristics inconsistent with those observed in the Dotted Lake batholith and the units are therefore interpreted to be distinct, unrelated plutons.

Petrogenetic Interpretation

The scale, homogeneity and mineralogical and geochemical characteristics of the Dotted Lake batholith place constraints on the petrogenesis of this unit. An origin by fractional crystallization of a more primitive primary magma is unlikely for several reasons. The large size of the unit would require a substantial volume of both a suitable primary magma as well as a cumulate component that is complimentary to the melt component. There is no evidence for the existence of such a primary magma, cumulates or intermediate magmatic compositions as inclusions in the Dotted Lake batholith. Furthermore, if it is assumed that the primary magma did not have a highly unusual composition, the same arguments limiting fractionation of mineral phases as an explanation for limited internal chemical variation within the Dotted Lake batholith can be extended to limit the involvement mineral phases expected to crystallize from a granitic magma in the upper crust. Consequently, it is probable that the composition of the Dotted Lake batholith approximately reflects a primary melt derived from some pre-existing rock.

The nature of possible source rocks is further constrained by the compositional characteristics of the Dotted Lake batholith. A significant metasedimentary component to the source is unlikely for several reasons. The mildly peraluminous character of the batholith contrasts with the strongly peraluminous nature (reflected in $\text{ASI} > 1.1$ as well as the presence of strongly peraluminous mineral phases like cordierite, garnet and sillimanite) of S-type granites recognized generally (Chappell and White, 1992) as well as elsewhere in the Superior Province (Breaks, 1989). Plagioclase feldspar is a major mineral phase in most metasedimentary rocks and would be expected to be a residual mineral phase in melting which would impart a negative Eu anomaly to the melt. The weak positive Eu anomalies characterizing the Dotted Lake batholith are inconsistent

with a noteworthy component of plagioclase in the residue. The depleted mantle Nd isotopic signature ($\epsilon_{Nd} = +2.3$) precludes the involvement of older metasedimentary rocks or younger metasedimentary rocks that were derived from the weathering of significantly older crust. Derivation from pre-existing intermediate to felsic igneous rocks is also unlikely for many of the same reasons (probable residual plagioclase would impart negative Eu anomalies and significantly older crust would impart a crustal isotopic signature). Granites interpreted to be derived by such a process elsewhere in the Superior Province (Beakhouse and McNutt, 1991) are more geochemically evolved than the Dotted Lake batholith.

The general geochemical characteristics of the Dotted Lake batholith are similar to those characterizing TTG suites worldwide that have been extensively interpreted to reflect partial melting of tholeiitic basalt at lower crustal or upper mantle depths (e.g., Martin, 1987; Drummond and Defant, 1990). Principal among these characteristics are $Al_2O_3 > 15\%$, low Rb and Rb/Sr, enriched LREE and depleted Y and HREE and mantle-type isotopic signatures. The residual mineral assemblage for the melting of tholeiitic basalt is a function of depth and imparts slightly different REE patterns to the resultant melt. To evaluate these possible models, trace element models for the partial melting of amphibolite, mafic garnet granulite (hydrous and anhydrous) and eclogite were evaluated as possible origins for the Dotted Lake batholith. In all cases, the possible mineral assemblages were constrained using ideal and empirical mineral compositions to approximately correspond to the major element composition of a tholeiitic basalt. A variety of possible initial source trace element compositions were tested generally ranging from 8-20X chondritic HREE with either flat or slightly LREE-enriched or LREE-depleted patterns. The most successful models were those involving 5-20% melting with an eclogitic residue (Figure 12). These models successfully reproduce the observed REE fractionation patterns and Eu anomalies when applied to normal (flat) REE tholeiitic basalt source compositions. Mafic garnet granulite (both hydrous and anhydrous) models reproduce the fractionation pattern for melting of 10X chondrite basaltic sources but tend to have weak negative Eu anomalies. Amphibolite melting models result in variable Eu anomalies, depending on the ratio of plagioclase to amphibole in the source, but generally fail to produce the observed REE fractionation and produce characteristic convex down HREE patterns. Although particular variants of most of these models can reproduce many or all of the observed geochemical characteristics, the eclogite model is preferred as it results in the best match with geologically reasonable input parameters.

An origin for the Dotted Lake pluton by partial melting of metasomatized mantle (sanukitoid model, e.g., Shirey and Hanson, 1984) is unlikely. The biotitic, mildly peraluminous character of the Dotted Lake batholith is atypical of the sanukitoid suite, which tends to be metaluminous with mafic mineralogy dominated by hornblende $\pm$ clinopyroxene. The Dotted Lake batholith does not have elevated Mg# and Ni and Cr abundances that would indicate equilibration with an ultramafic source although this could be explained by minor amounts of crystallization of mafic minerals, sulphides and oxides from a primary sanukitoid magma.

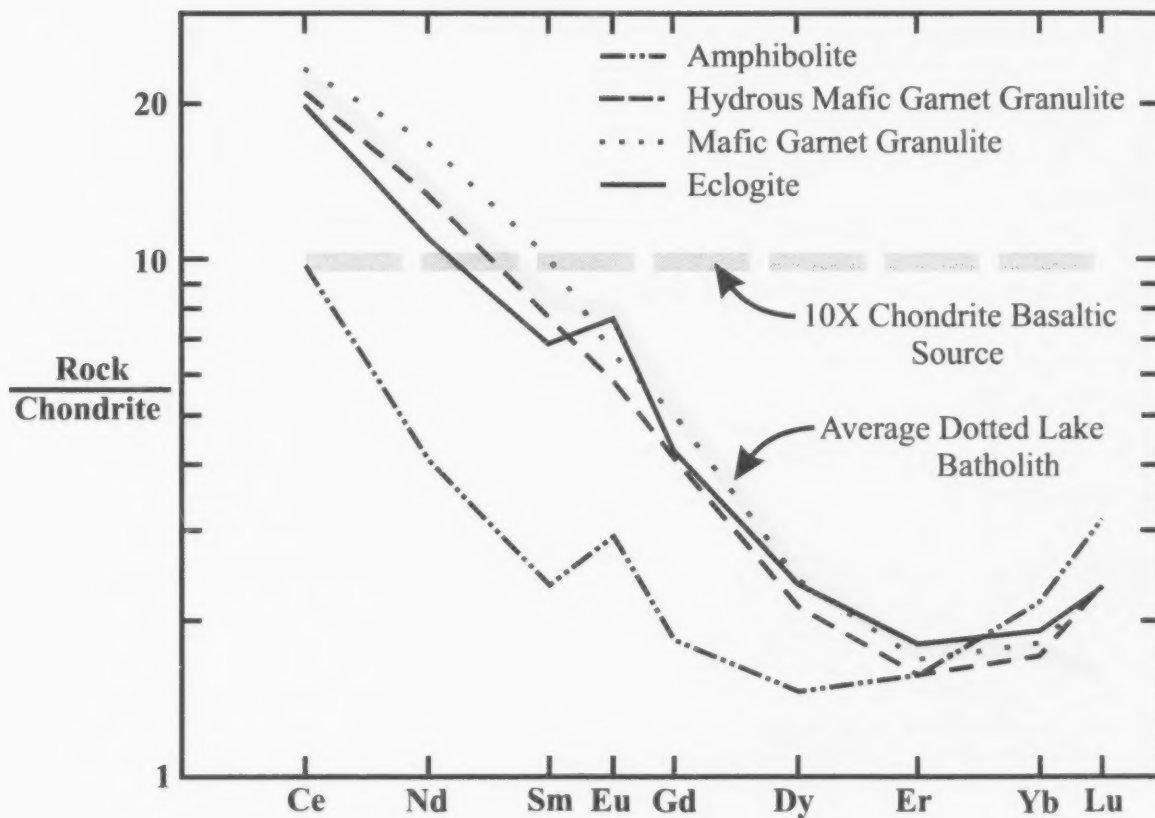


Figure 12. Comparison of average Dotted Lake batholith with examples of modeled melt compositions derived by batch equilibrium melting of a hypothetical unfractionated basaltic source with amphibolitic, mafic granulitic (hydrous and anhydrous) and eclogitic residues.

The preferred petrogenetic model for the Dotted Lake batholith is that it originated by small (10-20%) degrees of partial melting of a tholeiitic basalt leaving an eclogitic residue. This model would require that this melting take place at depths in excess of 50 kilometers (Wyllie et al., 1997).

Later Plutonic Group

Massive to weakly foliated, syn- to late-D₂ plutons are mineralogically and geochemically distinct from the gneissic tonalite and Dotted Lake suites. Although many of these plutons exhibit mineralogical and geochemical similarities, individual plutons generally have some distinct characteristics that serve to distinguish them from other plutons of this broad group that is informally referred to collectively as the Later Plutonic Group. The characteristics of the main phases of the individual plutons are discussed below.

Cedar Lake Pluton

The main 'granodiorite' phase of the Cedar Lake pluton lies mostly in the field of IUGS granodiorite with some overlap into the quartz monzodiorite field (Figure 3). Hornblende generally predominates over biotite (Figure 4) except for one anomalously leucocratic and pyroxene-bearing sample. Sphene is a ubiquitous and relatively abundant accessory mineral. Other primary accessory minerals include epidote, opaque oxide, apatite and zircon. Secondary minerals include chlorite (after biotite) and fine grained white mica, epidote and carbonate (after plagioclase feldspar).

Other components of the pluton are not volumetrically significant. A magnetic granodiorite phase is restricted to a narrow (less than 100 meters wide) zone along a portion of the southwest margin of the pluton. Dioritic to quartz monzonitic enclaves and dikes are widely distributed but generally constitute one percent or less of individual outcrops. Pegmatitic/aplitic dikes are notably abundant only along the southern contact of the pluton.

Petrology and Mineralogy

The main granodiorite phase is characterized by a hypidiomorphic granular texture with weakly to moderately well developed microcline megacrysts. Plagioclase composition is fairly uniform (An₃₄-An₂₅) and displays negligible or weak normal zonation. Plagioclase commonly has narrow albitic rims where it occurs in contact with microcline megacrysts that are attributed to very late magmatic or subsolidus interactions between these two phases. Plagioclase commonly displays weak to moderate, patchy or zone-controlled alteration to a fine-grained white mica-epidote-carbonate assemblage. Microcline occurs both as small, interstitial grains and larger megacrysts and is micropertthitic with albitic plagioclase lamellae within a relatively pure potassium feldspar host. Microcline megacrysts have small, zonally-arranged inclusions of most other mineral phases occurring in the rock. Plagioclase inclusions generally are either albite or oligoclase with albitic rims. These textural characteristics indicate that, despite the coarse grain size and

subhedral form of some of the microcline megacrysts, microcline is a late magmatic phase that post-dates most other mineral phases in the rock. Myrmekite is common along portions of the margins of microcline megacrysts where they are in contact with plagioclase. Primary mafic minerals present in the main granodiorite phase include both amphibole (edenite and, less commonly, magnesiohornblende), biotite and epidote. Minor amounts of chlorite occur as an alteration product of biotite. Minor oxide occurs primarily as magnetite octahedra and less commonly as Ti-bearing lamellar grains associated with both sphene and biotite. Minor amounts of sulphide, both pyrite and chalcopyrite, are present in several samples. Apatite, sphene and zircon are widely distributed, early (common as inclusions in amphibole) magmatic accessory phases.

Two samples (7262 and 7263) not distinguished from the main granodiorite phase in the field contain clinopyroxene in addition to amphibole and biotite. In addition to this mineralogical distinction, these two samples from the northeast part of the pluton are geochemically distinct as discussed below and may be a distinct intrusive phase.

The magnetic granodiorite phase is somewhat finer grained and more equigranular than the main granodiorite phase but is otherwise texturally and mineralogically similar to the latter.

Mafic enclaves and dikes exhibit a broad compositional range including diorite, monzodiorite, quartz monzodiorite and quartz monzonite (Figure 3) that are all characterized by a colour index > 28 (Figure 4). Plagioclase is generally relatively sodic (An_{24} to An_{36}) with local more sodic rims where it is in contact with microcline and in this respect is closely comparable to the enclosing main granodiorite phase. The intensity of alteration to a fine-grained assemblage of white mica – epidote – carbonate is highly variable even within a single thin section. This alteration may be either uniformly distributed throughout the grain, patchy or zone controlled and is attributed to deuteric alteration. Microcline generally occurs as small interstitial grains but may occur as megacrysts that poikilitically enclose other phases. In several cases, megacrysts were observed to transect the enclave/host contact and it is probable that late magmatic microcline megacrysts developed simultaneously in both the enclaves and the host granodiorite. Amphibole is the predominant primary mafic mineral although minor biotite (variously chloritized) is generally present and trace amounts of euhedral, twinned, primary epidote is present in some samples. Amphibole generally occurs as well formed, stubby prismatic crystals with a minor amount of fibrous (secondary?) amphibole occurring in some samples. Amphiboles (edenite and magnesiohastingsite) and biotites are more magnesian than those occurring in the host granodiorite phase. Sphene and apatite are relatively abundant as primary accessory minerals.

Geochemical Characteristics of the Main Granodiorite Phase

The main granodiorite phase is metaluminous and characterized by intermediate SiO_2 (62-67%) and Mg # (45-56) with respect to other granitoid rocks associated with the Hemlo greenstone belt. In comparison to the gneissic tonalite and Dotted Lake suites, it, like most of the later plutonic group, has more CaO and K_2O and less Na_2O reflecting the

greater abundance of microcline and more calcic nature of the plagioclase feldspar. It is also characterized by somewhat greater abundance of P_2O_5 , Y, Nb, Zr, Th and Ni in comparison with the earlier plutonic rocks. All elements display coherent trends over a limited compositional range on Harker variation diagrams (Figure 13). The general nature of the major element trends (e.g. CaO, TiO_2 , MgO, Fe_2O_3 , P_2O_5 decreasing and K_2O increasing with SiO_2) are generally compatible with those expected from crystal-liquid fractionation originating either by fractional crystallization or partial melting. Trace element trends exhibit some parallels to those displayed by major elements but are less well developed and the abundance of many trace elements is relatively uniform within the main granodiorite phase.

REE patterns are moderately to strongly fractionated ($Ce_N/Yb_N = 32-64$) with abundant LREE ($Ce_N = 120-180\times$ chondrite) and weak negative Eu anomalies (Figures 14 and 15). The magnitude of the negative Eu anomaly is positively correlated with CaO and Al_2O_3 and negatively correlated with SiO_2 suggesting that it is not related to fractional crystallization of plagioclase but is rather a primary melt characteristic. Although there is a range of REE fractionation with a weak tendency to fanning patterns, the overall general parallelism of patterns suggests that fractional crystallization involving amphibole is not primarily responsible for the observed variation. Fractional crystallization involving removal of both plagioclase and amphibole (most likely based on petrographic observations) partially mitigates the foregoing arguments but would result in bulk distribution coefficients near unity for LREE which would not explain the observed range in REE abundances. Consequently, although fractional crystallization may be responsible for some of the minor observed variation within this unit, the variability displayed by this unit is interpreted in large part to reflect a range of primary melt characteristics.

Petrogenetic Interpretation of the Main Granodiorite Phase

Nd isotopic data indicate a depleted mantle-type ($\epsilon_{Nd} = +1.8$ to $+3.1$) signature, which together with the distinctly metaluminous character of these rocks and the absence of prominent negative Eu anomalies, limits the involvement of pre-existing felsic crustal or sedimentary rocks. The most probable source rocks are either pre-existing mafic (basaltic) crust as inferred for the Dotted Lake batholith and tonalitic components of the belt-bounding batholiths or direct partial melting of metasomatized mantle as envisaged in the sanukitoid model (Shirey and Hanson, 1984).

Attempts to model the composition of the main granodiorite phase of the Cedar Lake pluton by partial melting of basalt with either amphibolitic, mafic granulitic (with or without hornblende and/or garnet) or eclogitic residues were not successful. The weak negative Eu anomalies were only reproduced in models with a significant residual plagioclase component which makes it difficult to explain the bulk major element composition and the degree of REE fractionation. A wide range of garnet and/or amphibole-bearing residual assemblages can account for the observed HREE depletion but fail to explain the degree of fractionation and, in particular, the high LREE abundances. This objection can be overcome by appealing to an unusually LREE-

Symbol legend - Figure 13

Cedar Lake Pluton

- Main Granodiorite Phase
- Magnetic Granodiorite Phase
- ◆ Samples 7262 / 7263
- Dioritic enclaves and dikes
- Sample 7018B
- ◈ Leucogranite dike

Figure 13. Harker variation diagrams for the Cedar Lake pluton. Diagrams on the right are enlargements of portions of the diagrams on the left.

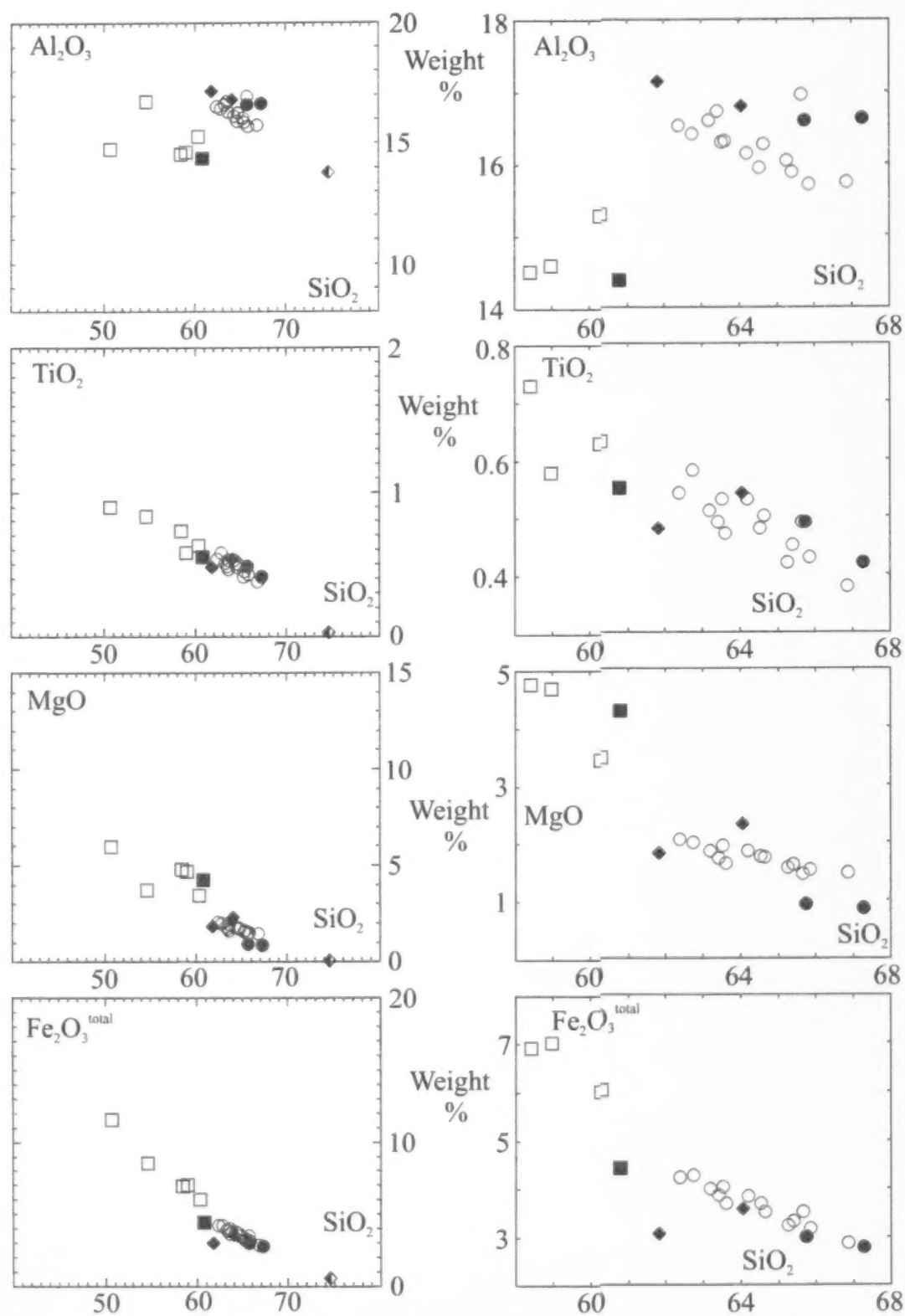


Figure 13. Harker variation diagrams for the Cedar Lake pluton. Diagrams on the right are enlargements of portions of the diagrams on the left.

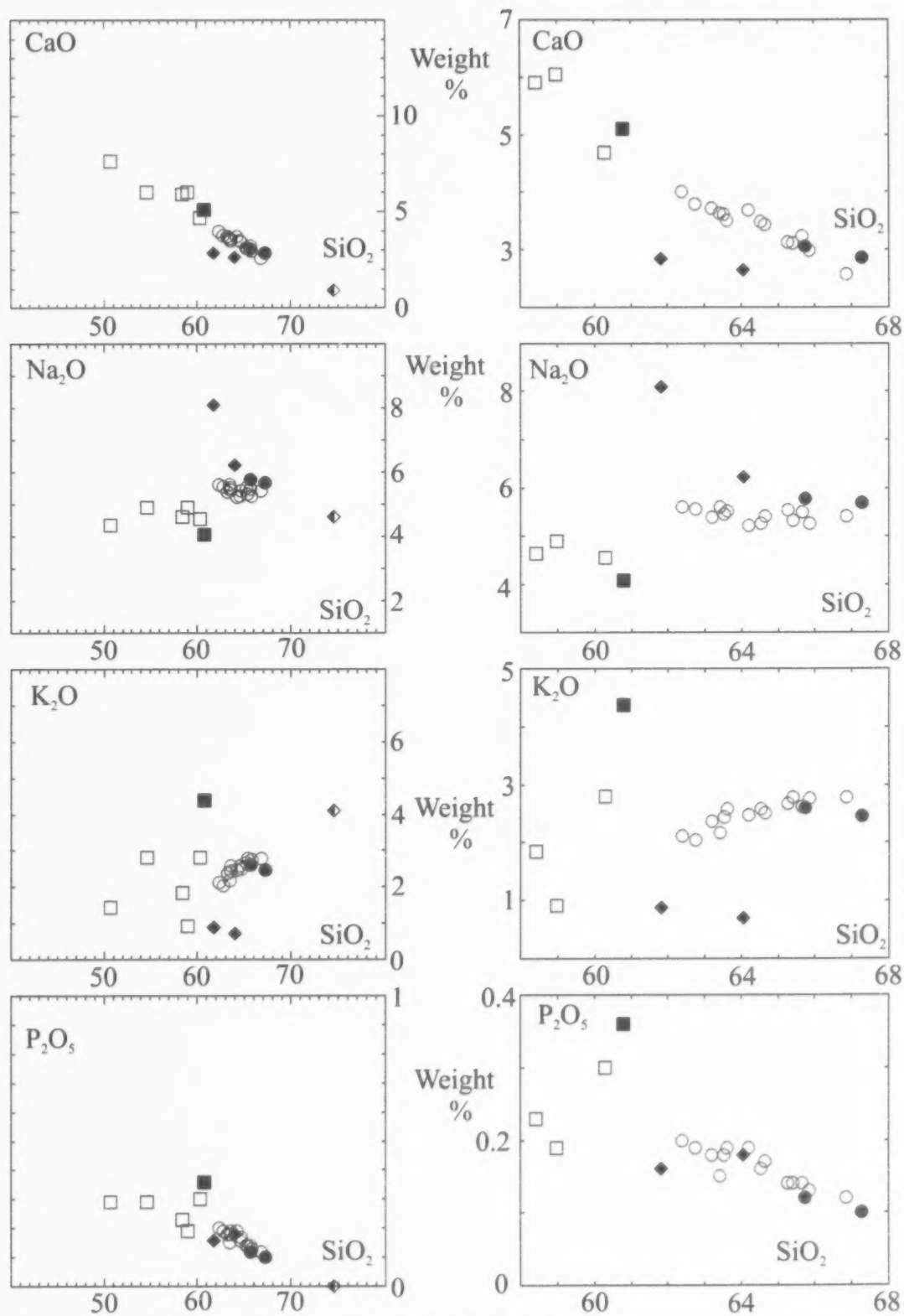


Figure 13. Harker variation diagrams for the Cedar Lake pluton.

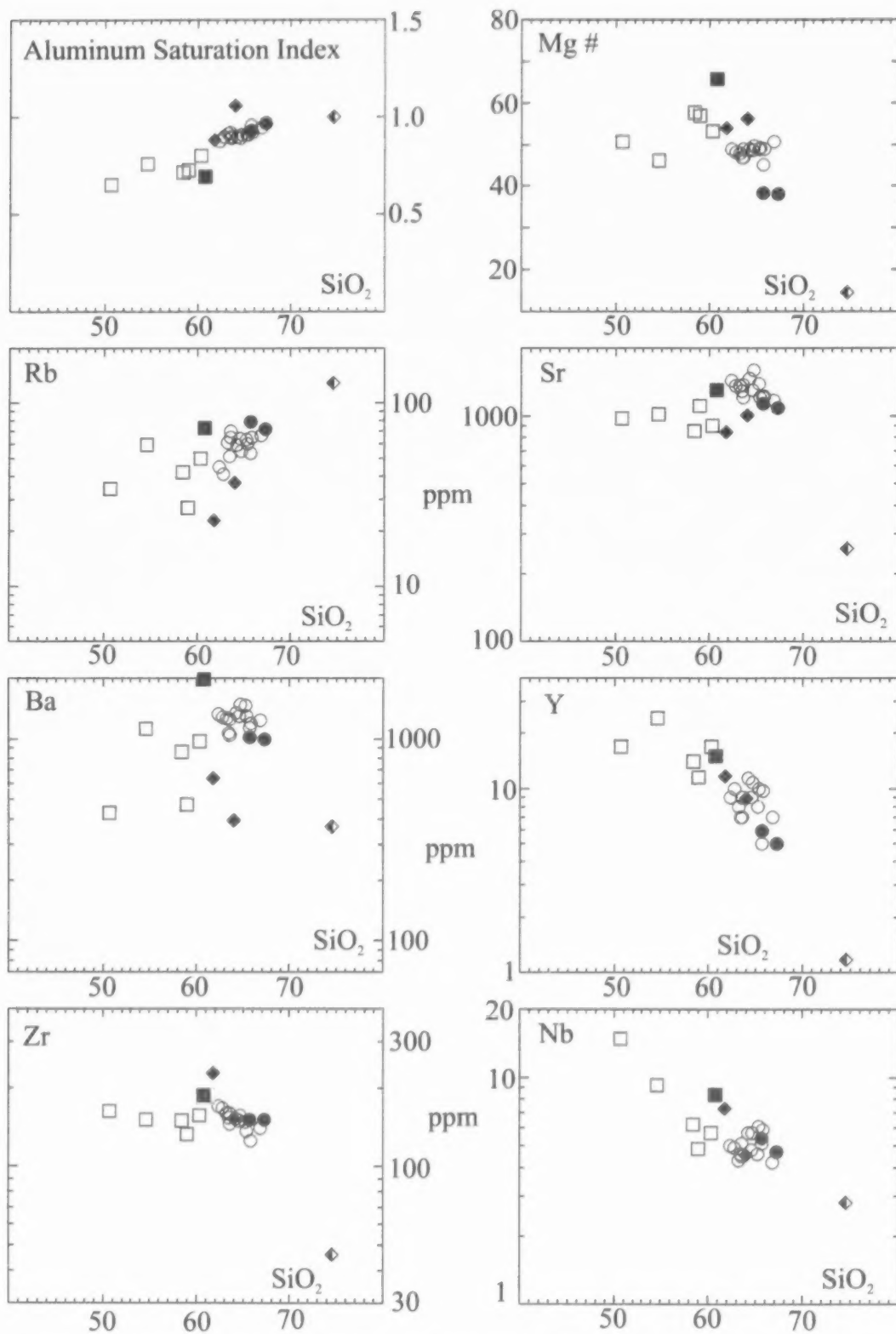


Figure 13. Harker variation diagrams for the Cedar Lake pluton.

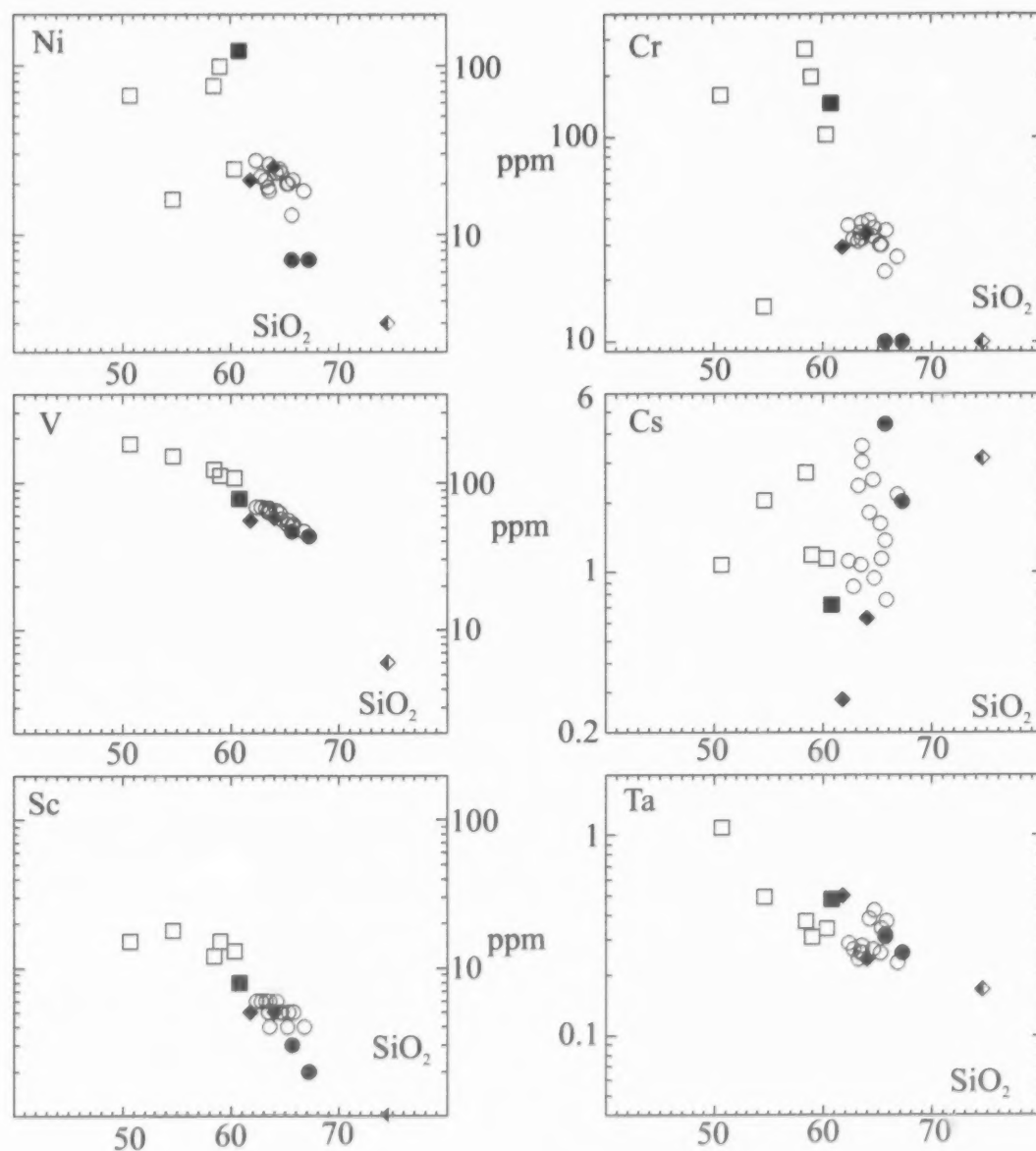


Figure 13. Harker variation diagrams for the Cedar Lake Pluton.

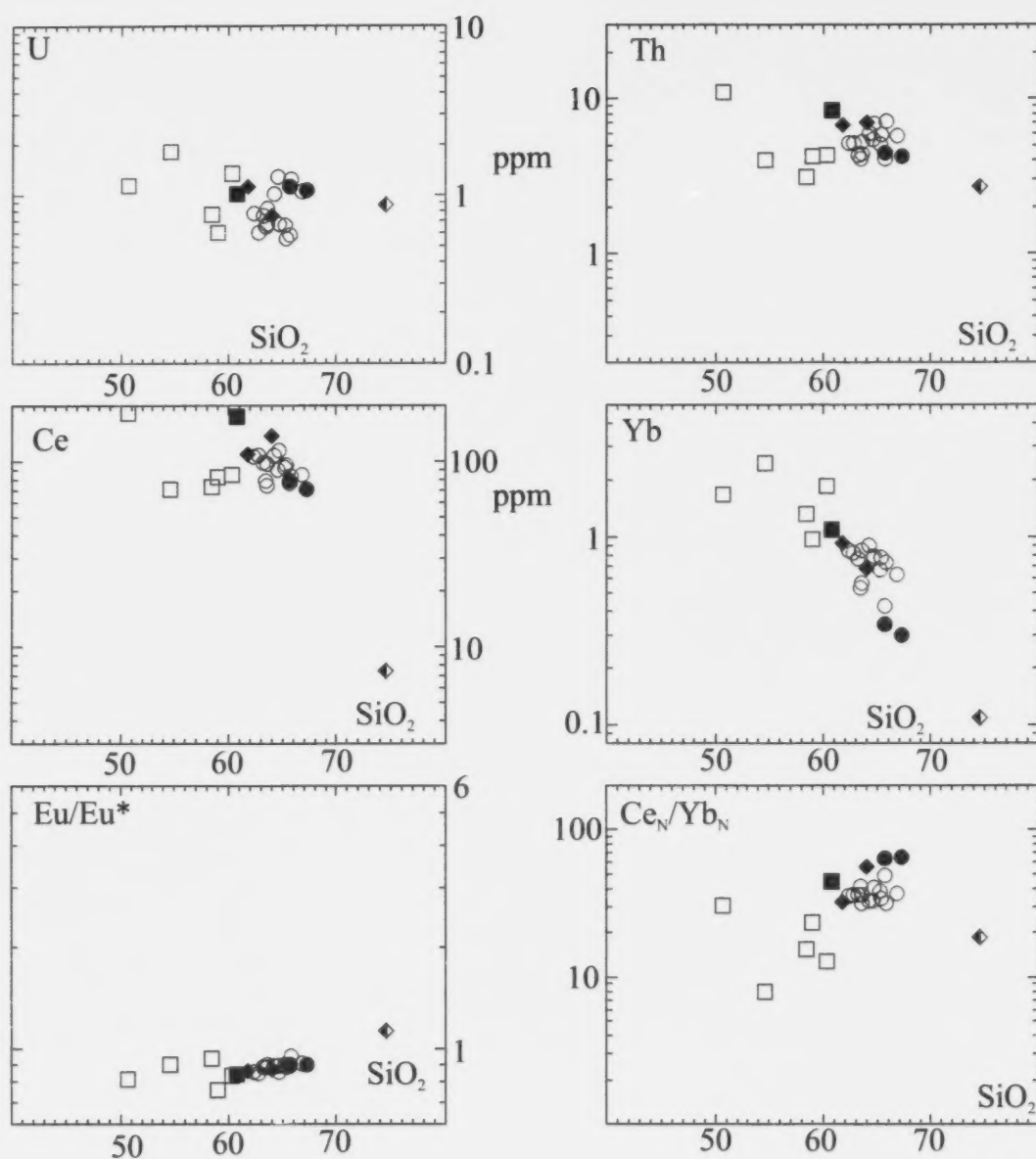


Figure 13. Harker variation diagrams for the Cedar Lake pluton.

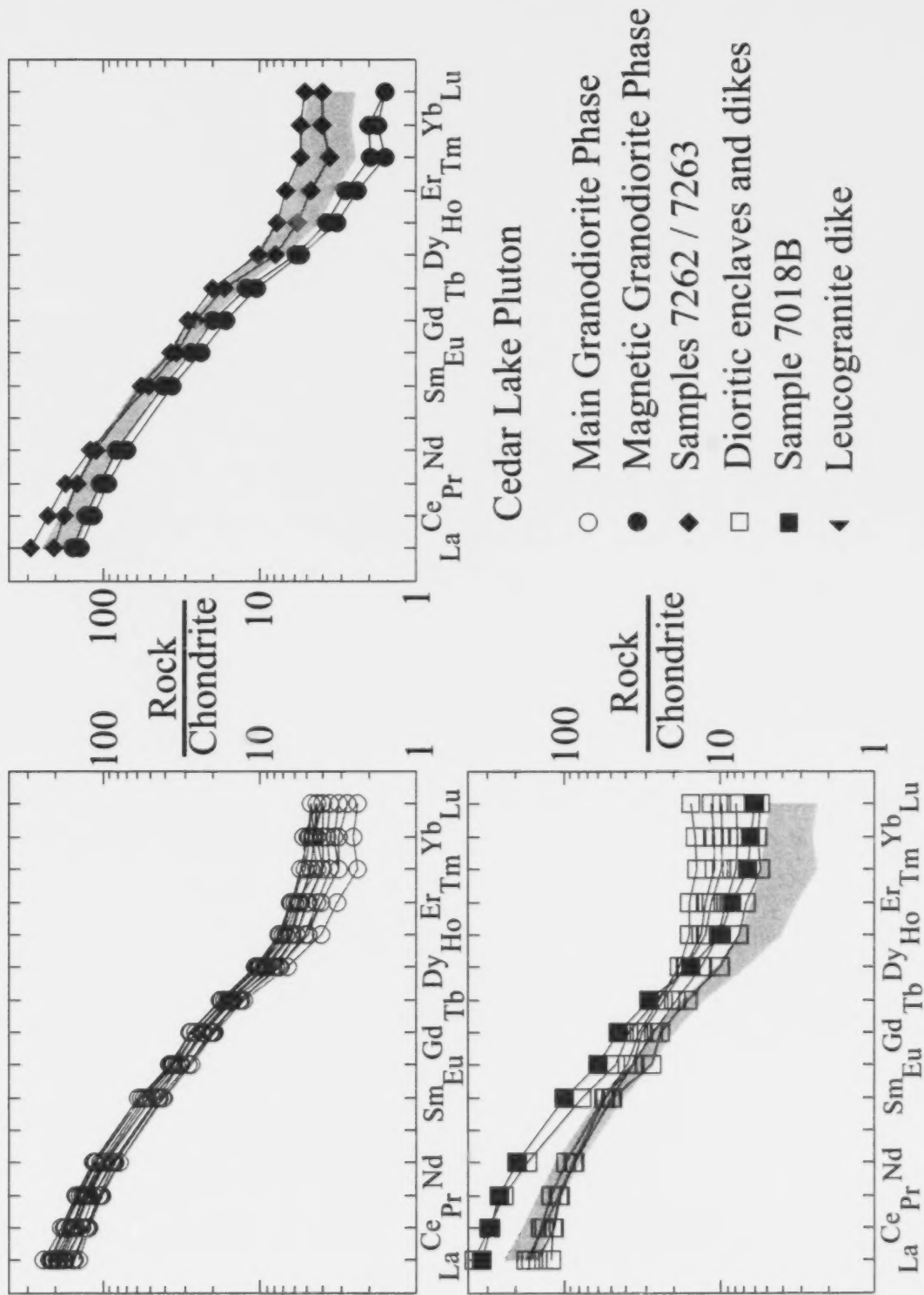


Figure 14. Chondrite normalized REE abundances for various components of the Cedar Lake pluton. The compositional spectrum of main granodiorite phase samples illustrated in the upper left diagram are reproduced as a stippled area in the other diagrams to facilitate comparison.

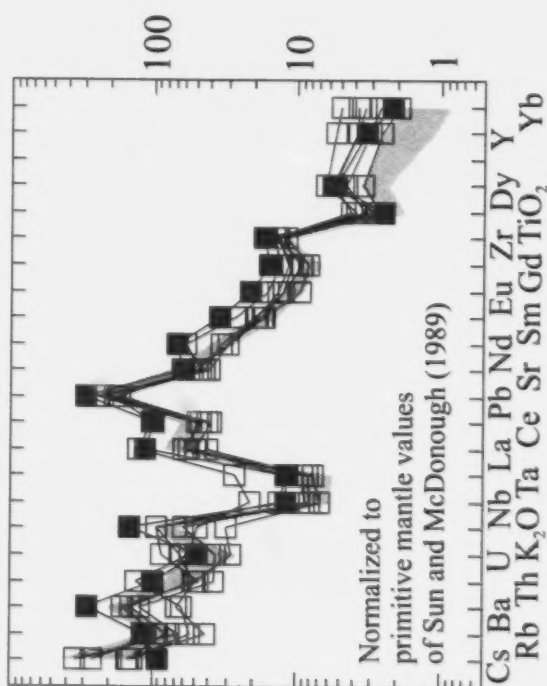
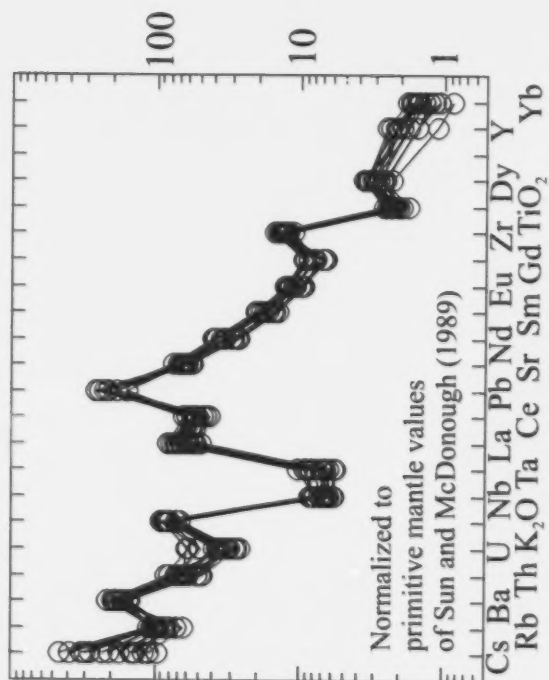
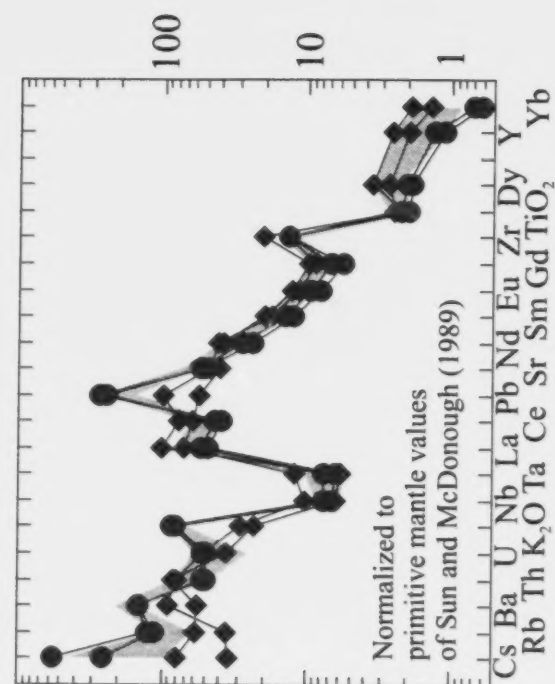


Figure 15. Primitive mantle normalized multi-element diagram for samples from the Cedar Lake pluton. The compositional spectrum of the main granodiorite phase (upper left diagram) is reproduced as a stippled pattern in the other diagrams to facilitate comparison. Normalization values from Sun and McDonough (1989).

enriched basaltic source. The degree of enrichment necessary can be estimated from the estimated range of possible bulk distribution coefficients for Ce. Using partition coefficients for rhyolitic and dacitic rocks (Arth, 1976) and estimates of proportions of mineral phases present in a quartz tholeiite (Green and Ringwood, 1967) for hornblende and garnet-bearing assemblages at a variety of pressures, it is estimated that the bulk distribution coefficient for Ce ranges from a high of approximately 0.85 for an amphibolite to a low of approximately 0.3 for a mafic garnet granulite. Assuming 10% melting and the lowest bulk distribution coefficient, the observed Ce abundances in the Cedar Lake pluton (~76-114 ppm) would still require a Ce content in the putative source basalt between 27 and 41 ppm (44x to 67x chondrite). Such LREE-enriched basaltic rocks have modern analogues (primarily ocean island basalts and continental flood basalts as well as certain anomalous (P-type) MORB (Wilson, 1989)) and are known from, but exceeding rare in, Archean greenstone belts (cf. Sage et al., 1996). In summary, a basalt melting model is only acceptable if an unusual basaltic source composition is assumed and this model is consequently regarded as a possible, but not probable, explanation for the generation of the main granodiorite phase of the Cedar Lake pluton.

Direct partial melting of LILE-enriched mantle to produce monzodioritic primary magmas that may subsequently evolve to granodioritic compositions (hereafter referred to as the sanukitoid model) was originally proposed as an explanation for certain granitoid rocks in the Rainy Lake area by Shirey and Hanson (1984). This model has since been applied to many areas within the Superior Province (e.g., Stern et al., 1989; Sutcliffe et al., 1990; Stern and Hanson, 1991; Beakhouse et al., 1999). The characteristics of primary sanukitoid magmas include mantle-type radiogenic isotope ratios, high Mg#, as well as high abundances of Ni, Cr, Zr, Sr and K and strongly LREE-enriched, fractionated REE profiles. Within this model the high Mg#, Ni and Cr are interpreted to reflect equilibration with an ultramafic source and the high abundances of LILE are interpreted to be inherited from a source that was metasomatically enriched in these elements. The isotopic characteristics require that this metasomatism occurred less than ~100-200 Ma prior to melting. Certain of these characteristics (mantle-type Nd isotope signature and LILE and REE abundances) are shared by the Cedar Lake pluton but Mg# (~50 vs >60), Cr (~30 ppm vs >200 ppm) and Ni (~20 ppm vs >150 ppm) are significantly lower than inferred primary sanukitoid magmas. Consequently, the main granodiorite phase of the Cedar Lake pluton cannot reflect a primary sanukitoid magma and could only be related to this model as a highly evolved member of the sanukitoid suite.

Other Granodioritic Phases within the Cedar Lake Pluton

Two different groups of granodioritic rocks were distinguished from the main granodiorite phase based on field and petrographic criteria discussed above. Geochemical data supports the distinction of these units from the main granodiorite phase.

The magnetic granodiorite phase occurring along the southwest margin of the pluton, originally distinguished in the field on the basis of its more magnetic character and subtle textural differences, is geochemically distinct from the main granodiorite phase in several important respects. Relative to the main granodiorite phase, the magnetic granodiorite is characterized by generally higher SiO_2 , Al_2O_3 and Rb and notably lower MgO, Mg#, Ni and Cr (Figure 13). It is also characterized by lower overall REE abundances (Figure 14), particularly for the HREE resulting in highly fractionated patterns ($\text{Ce}_\text{N}/\text{Yb}_\text{N} \sim 65$). The unit has comparable depleted mantle-type Nd isotopic signature ($\epsilon_{\text{Nd}} = +2.6$) to the range for the main granodiorite phase. These characteristics render this unit less similar to the sanukitoid suite and closer to the characteristics of TTG suite plutons derived by partial melting of tholeiitic basalt although the REE abundances are still sufficiently high that such a model would only be acceptable for an unusually REE enriched basaltic source.

The distinction of the clinopyroxene-bearing granodiorite samples (7262 and 7263) from the main phase granodiorite is also supported by differences in their geochemical characteristics. These samples diverge from trends for the main granodiorite phase for Al_2O_3 , MgO, Fe_2O_3 , CaO, Na_2O , K_2O , Mg#, Rb, Ba, Sr and Cs. The divergence is especially noteworthy for elements occurring primarily in the feldspars and the very sodic character ($\text{Na}_2\text{O}/\text{K}_2\text{O} \sim 9$ vs 2-3) is particularly striking and unusual. The Mg# is elevated with respect to that characterizing the main granodiorite phase but does not correlate with higher Cr and Ni abundance as might be expected if these rocks had a sanukitoid affinity.

Dioritic Phases within the Cedar Lake Pluton

The volumetrically minor dioritic (s.l.) units within the Cedar Lake pluton include diffusely bounded enclaves and dikes that are interpreted to be co-magmatic with the main granodiorite phase (samples 7004B, 7008B, 7009B, 7033B and 7217) as well as rare sharply bounded dikes with chilled margins (sample 7018B). These rocks are more primitive with respect to their SiO_2 abundance and a wide range of major and trace elements (Figures 13 to 15). Mg# and Ni and Cr abundance are generally elevated but exhibit a considerable range and actually show a weak positive correlation with SiO_2 . Two samples have depleted mantle type Nd isotopic signature ($\epsilon_{\text{Nd}} = +1.9$ to $+2.3$). Most samples have moderately fractionated REE with weak negative Eu anomalies. The exceptions to this generalization (samples 7008B and 7018B) differ in having more elevated LREE and consequently more highly fractionated REE abundances. In spite of the relatively primitive character of the dioritic phases based on their elevated Mg# and lower SiO_2 content, these rocks are characterized by relatively high K_2O , Rb, Cs, U and Th abundances. The higher abundance of these elements could be a primary characteristic of the magmas or could reflect, in part, the interaction of these magmas with the granodioritic phases. The overall characteristics of these rocks are closer to those of primary sanukitoid magmas and this origin (partial melting of metasomatically enriched depleted mantle is the favored interpretation for these rocks.

Cedar Lake Pluton Summary

The Cedar Lake pluton consists of a main granodiorite phase together with several areally restricted granodiorite phases that are geochemically distinct from the main phase and widely distributed, but volumetrically minor, dioritic phases. None of these phases have characteristics that are permissive of extensive involvement of pre-existing felsic crust or metasedimentary rocks. Some of these units, including the volumetrically dominant main granodiorite phase, have geochemical characteristics permissive of an origin by partial melting of tholeiitic basalt, but only if this basaltic crust had unusual characteristics. Such an origin is considered unlikely for the dioritic and clinopyroxene-bearing granodiorite units which have characteristics more closely comparable to those of the sanukitoid suite. It is possible that the other phases are more evolved members of the sanukitoid suite although the pluton may also represent a hybridization of variously evolved sanukitoid and TTG suite magmas.

Heron Bay Pluton

The Heron Bay pluton consists of hornblende-biotite granodiorite with limited compositional variation but considerable textural diversity. The textural variation is gradational and includes medium grained, transitional and plagioclase subporphyritic varieties. All textural varieties of the pluton lie primarily in the field of IUGS granodiorite (Figure 3) and are closely comparable to the Cedar Lake pluton in this respect. Hornblende predominates over biotite and color index ranges from 6 to 18 except for a small subset of samples that are somewhat more mafic (Figure 4). Dioritic enclaves and ultramafic clots are rare in all of the textural variants that comprise the Heron Bay pluton.

Petrology and Mineralogy of Main Phases

The textural variation arises primarily from differences in the crystal habit of plagioclase and the grain size of the other primary constituents of the rock. A hypidiomorphic granular texture characterizes the medium grained variety with the grain size of plagioclase and quartz being approximately equal. Plagioclase is a relatively early crystallizing phase and is subhedral to anhedral. Microcline varies from relatively smaller (< 1 mm) interstitial grains to moderately well developed megacrysts up to 2 centimeters in diameter. The plagioclase subporphyritic variety is characterized by equant, subhedral to euhedral plagioclase, generally 2-3 mm in diameter, within a slightly finer grained matrix containing the same mineral phases that are present in the medium grained variety. Microcline generally occurs as relatively finer grained, interstitial grains. The transitional variety is characterized by the presence of subhedral to euhedral plagioclase as occurs in the plagioclase subporphyritic variety but overall grain size is more similar to that of the medium grained variety.

Plagioclase composition is generally comparable in all textural varieties although average plagioclase is slightly more sodic (An_{28} vs An_{32}) in the plagioclase subporphyritic variety

which is attributed, in part, to more sodic ($\sim\text{An}_{24}$) rim compositions. Microcline is microperthitic and commonly has associated myrmekite where it occurs in contact with plagioclase.

Both amphibole and biotite are primary mafic minerals. Biotite is commonly partially altered to chlorite. Microprobe analyses indicate calcic amphibole with a restricted compositional range ($\text{Si} = 6.38\text{--}6.65$; $\text{Mg}/\text{Mg}+\text{Fe} = 0.48\text{--}0.52$). Similarly, biotite is characterized by a restricted compositional range. Epidote and sphene are common, relatively abundant accessory minerals. The former occurs both as a fine-grained alteration product of plagioclase as discussed below and larger crystals that are commonly subhedral to euhedral and in some cases display simple twinning. These larger, twinned crystals are interpreted to be primary magmatic epidote. Traces of apatite are ubiquitous and traces of zircon and opaque oxides occur in some samples.

Primary mineralogy is generally well preserved. Secondary minerals include chlorite after biotite and fine grained, cloudy (epidote, white mica, carbonate) alteration of plagioclase feldspar. Traces of sulphide occur in some samples.

Geochemical Characteristics

The three texturally defined phases of the Heron Bay pluton have similar geochemical characteristics with the exception of a small subset of samples discussed below from the northwest corner of the pluton. The main part of the pluton is characterized by moderately metaluminous compositions with 65–69% SiO_2 . Abundances of CaO and a wide range of HFSE are low relative to that characterizing many of the other units within the later plutonic group.

Harker variation diagrams (Figure 16) indicate the relatively uniform chemical composition of samples containing greater than 65% SiO_2 . All three of the textural variants of the pluton have overlapping compositional fields with comparable trends. The lower SiO_2 samples, including two from each of the plagioclase subporphyritic (samples 7118 and 7119) and transitional (samples 7117 and 7159) groups, correspond to those having a relatively higher colour index referred to above. These four samples depart the trends displayed by the higher SiO_2 samples for many elements, most notably Al_2O_3 , MgO, Mg#, Ni and Cr. These characteristics suggest that the lower SiO_2 rocks are more geochemically primitive although the abundances of K_2O and Rb do not notably decrease with decreasing SiO_2 .

REE (Figure 17) exhibit moderate fractionation with near chondritic HREE and negligible Eu anomalies. The higher SiO_2 samples are all very closely comparable although sample 7128 (plagioclase subporphyritic) has lower LREE and a somewhat less fractionated pattern. The lower SiO_2 samples exhibit less fractionated REE patterns due to more abundant HREE.

Symbol legend - Figure 16

Heron Bay Pluton

- Medium-grained Granodiorite
- Transitional Granodiorite
- △ Transitional Granodiorite (high-Mg)
- × Plagioclase Subporphyritic Granodiorite
- + Plagioclase Subporphyritic Granodiorite (high-Mg)

Figure 16. Harker variation diagrams for the Heron Bay pluton.

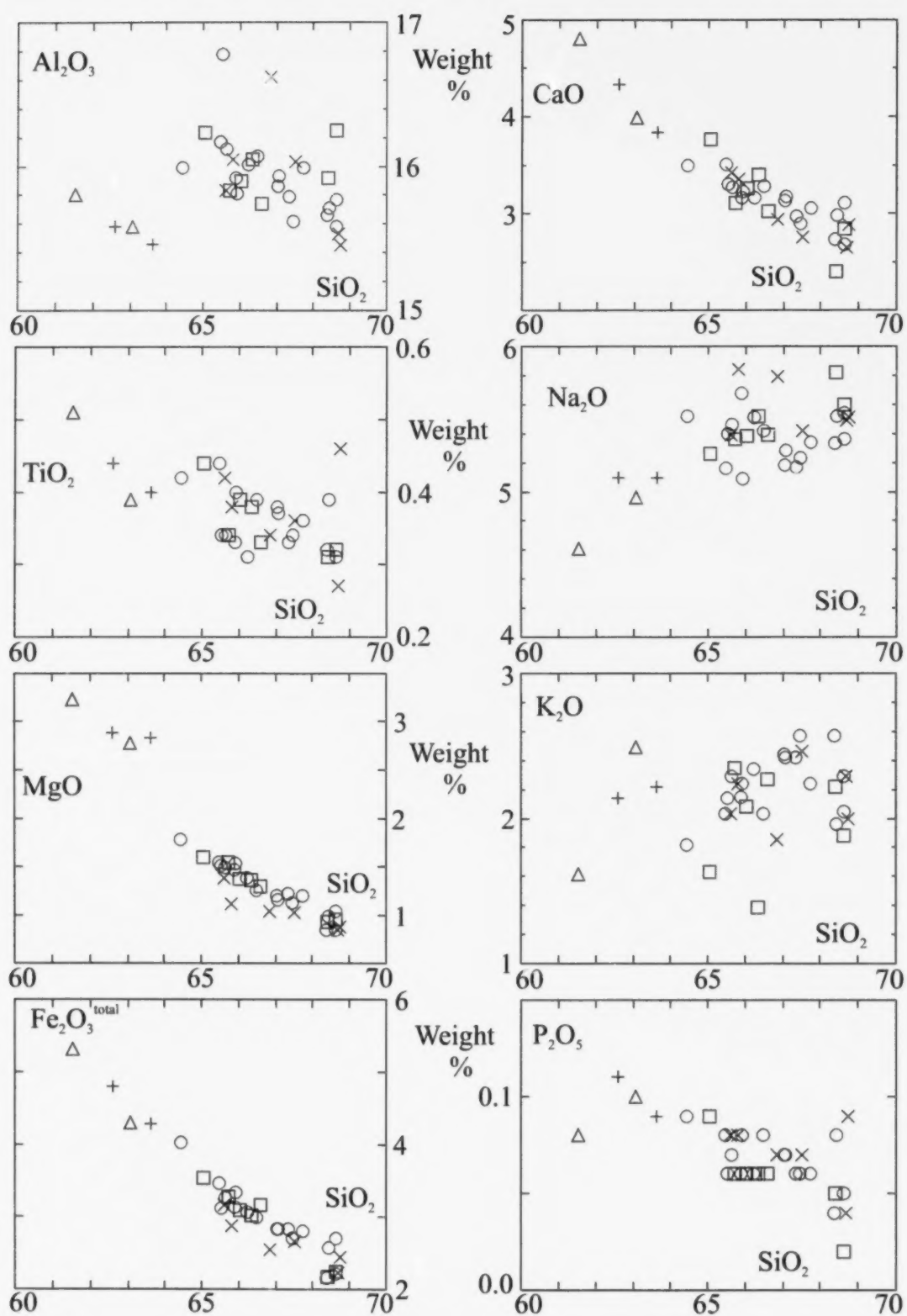


Figure 16. Harker variation diagrams for the Heron Bay pluton.

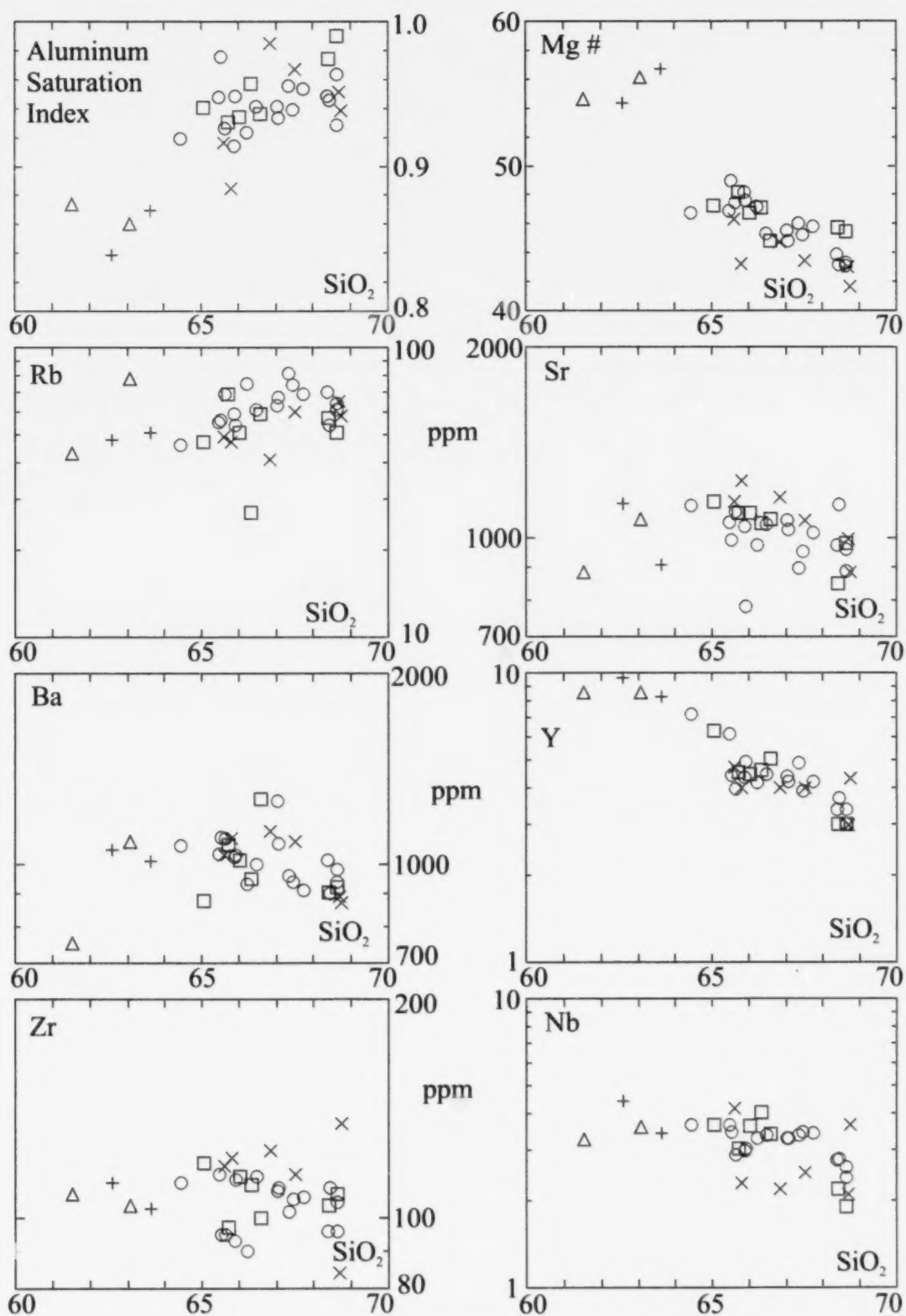


Figure 16. Harker variation diagrams for the Heron Bay pluton.

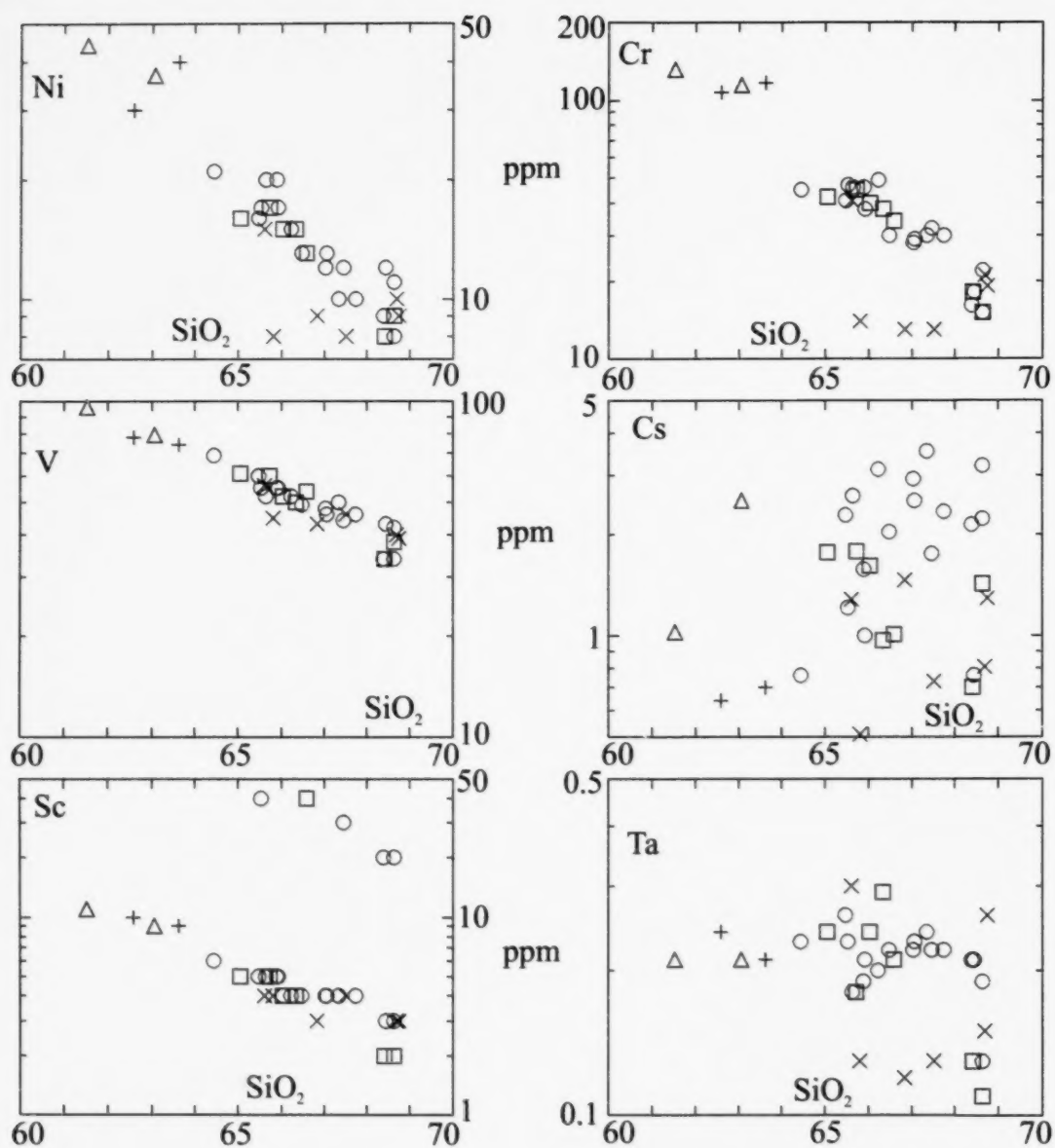


Figure 16. Harker variation diagrams for the Heron Bay pluton.

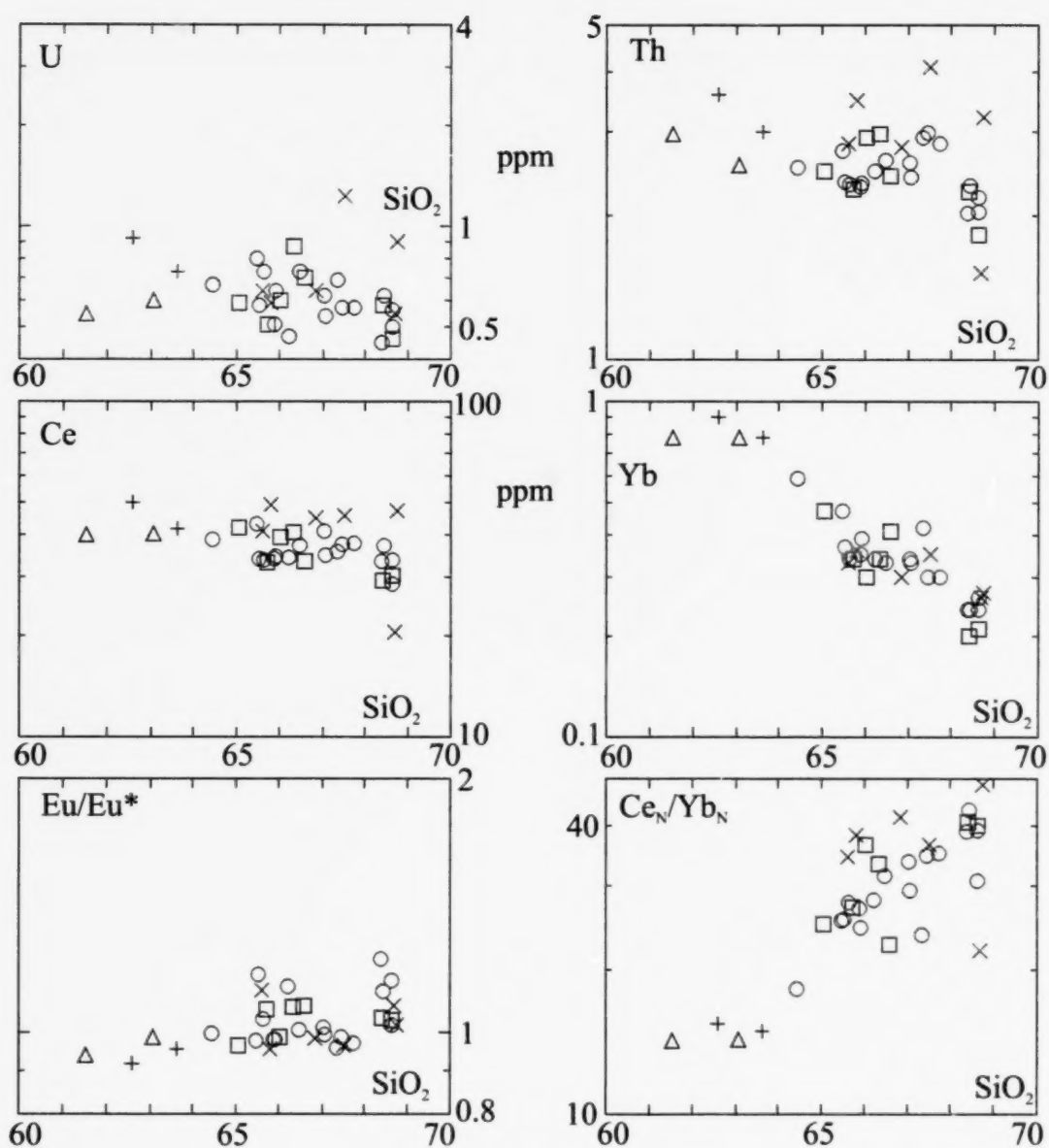


Figure 16. Harker variation diagrams for the Heron Bay pluton.

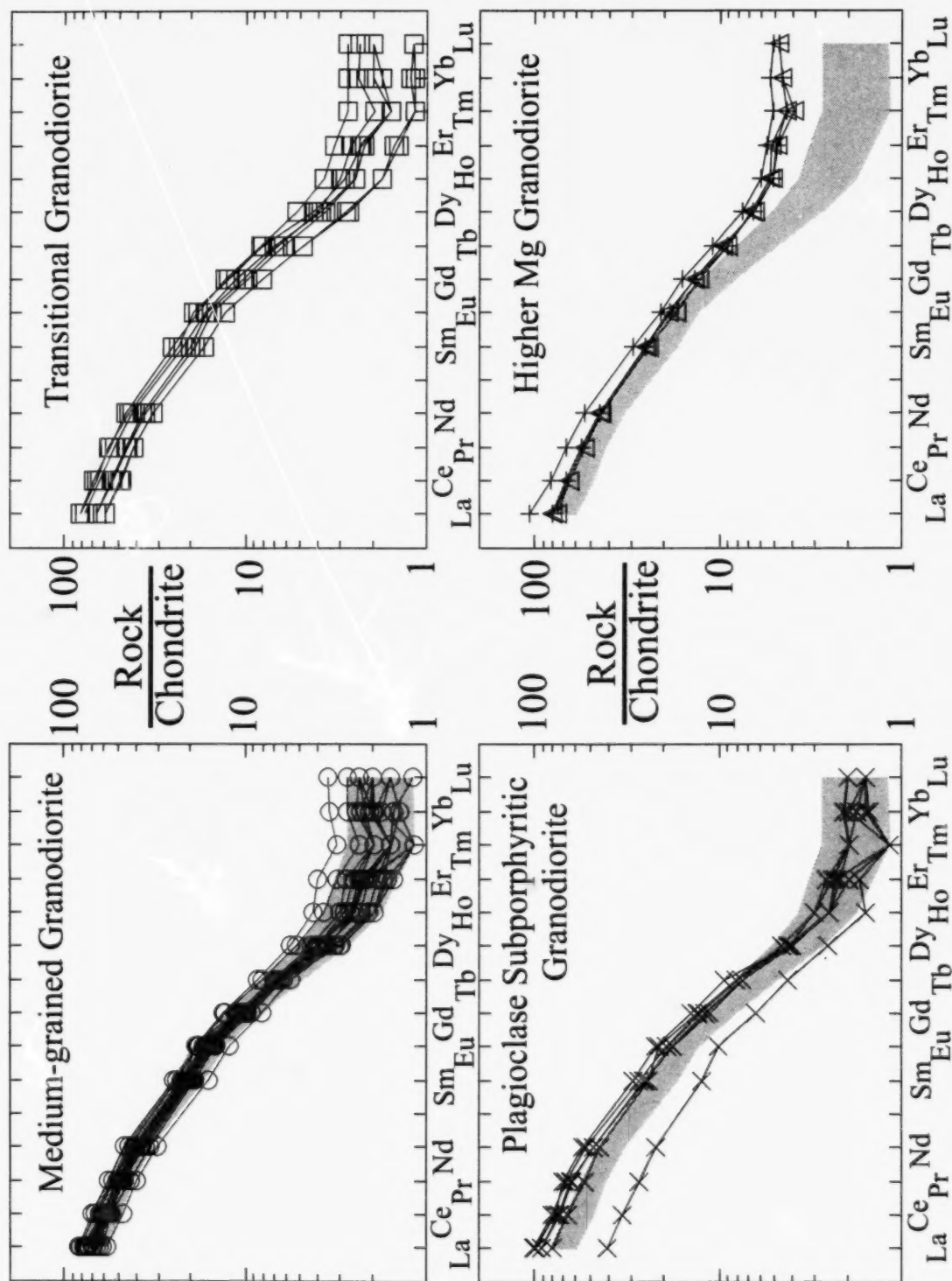


Figure 17. Chondrite normalized REE abundances for different components of the Heron Bay pluton. Chondrite normalization values are those of Sun and McDonough (1989). The range of REE spectra for the transitional granodiorites, excluding those characterized by higher MgO abundances, is reproduced as a stippled pattern in the other diagrams to facilitate comparison..

Nd isotopes ($\epsilon_{Nd} = +1.9$ to $+2.7$) are comparable to Archean depleted mantle and rule out significant involvement of much older felsic crust. Inherited zircons as old as 2724 Ma were identified in several samples selected for U-Pb geochronology (Corfu and Muir, 1989; Davis et al., 1998) and indicate that the pluton has interacted with zircon-bearing units comparable in age to the belt-bounding batholiths. The Nd isotopic system would be relatively insensitive to significant involvement of felsic crust less than 40 Ma older than the pluton, but as discussed below, this is considered unlikely on other grounds.

Petrogenetic Interpretation

The absence of any inclusions of older felsic crust or metasedimentary rocks and the uniformity of geochemical characteristics within the Heron Bay pluton require that any involvement of older crust occurred at a stage of magma generation that permitted the removal of any crystalline residual component and homogenization of the resultant magma. The characteristics of the component derived from such an older crustal component would consequently be those of a partial melt of a feldspar-rich rock which would include prominent negative Eu anomalies, and depletion of Sr. This is unlikely in view of the observed negligible to weakly positive Eu anomalies and Sr abundance in the range of 780-1230 ppm and averaging 1024 ppm. Such melts would also be expected to have lower abundances of Ni and Cr than are observed and have lower Mg# and more tendency to peraluminous compositions. The presence of an inherited zircon component is interpreted to indicate that the Heron Bay pluton was intruded through crust as old as the belt-bounding batholiths but that neither such pre-existing felsic igneous rocks or metasedimentary rocks contributed significantly to the bulk composition of the pluton. In the absence of a felsic igneous or sedimentary crustal component, the Heron Bay pluton is consequently interpreted to be derived from partial melting of mafic crust (TTG model) or direct melting of the mantle (sanukitoid model) or a hybrid of the two.

The predominant higher (65-69%) SiO_2 component of the Heron Bay pluton has geochemical characteristics that are broadly consistent with the TTG model. These characteristics include the sodic, metaluminous character together with elevated Al_2O_3 (15.5-16.5%) and low Y and HREE abundances. Mg# and Ni and Cr abundances are within the high end of the ranges generally observed for rocks of interpreted TTG affinity (c.f., Martin, 1987; Drummond and Defant, 1990). The higher SiO_2 component of the Heron Bay pluton is characterized by moderately to highly fractionated REE with near chondritic HREE and negligible to weakly positive Eu anomalies. These characteristics are similar to those of the type 2 tonalitic to granodioritic gneissic components occurring in the belt bounding batholiths that can be successfully modeled as partial melts of tholeiitic basalt if the putative source is assumed to have somewhat fractionated and elevated REE (see Figure 8 and associated discussion).

The less abundant, lower SiO_2 component of the Heron Bay pluton is not readily reconciled with the TTG model. Relative to the higher SiO_2 component of the Heron Bay pluton, and rocks of inferred TTG affinity from elsewhere, these rocks have higher Mg# (54-57) and greater abundance of MgO (~3%), Ni (30-44 ppm) and Cr (107-132 ppm). They are also characterized by higher abundances of Y and HREE than is typical of TTG

plutons. The higher Mg#, Ni and Cr suggests that these rocks may represent either higher degrees of melting or they were derived from a more mafic source in which these geochemical parameters were elevated. A higher degree of melting is considered to be a less likely explanation in view of the apparent discontinuities in the trends for MgO, Ni and Cr (Figure 16). In addition, the abundances of elements generally regarded to be incompatible (e.g., K₂O, Rb and U) are comparable for the higher and lower SiO₂ components but might be expected to decrease in abundance with increasing degree of melting. The preferred interpretation for the lower SiO₂ component is that it is derived from a more mafic or ultramafic source than the higher SiO₂ component. Mg# and Ni and Cr abundances are lower than that interpreted to characterize primary sanukitoid magmas (c.f., Shirey and Hanson, 1984; Stern et al., 1989) but these rocks may represent more fractionated components of the sanukitoid suite.

Gowan Lake Pluton

The dominantly monzodioritic composition (Figure 3) and mafic character of the Gowan Lake pluton are distinctive characteristics that set this unit apart from others associated with the Hemlo greenstone belt. The mafic mineralogy is also distinctive with hornblende, locally with clinopyroxene cores, greatly predominating over biotite (Figure 4). Opaque iron oxides are relatively abundant and account for the positive aeromagnetic anomaly associated with this pluton.

Petrology and Mineralogy of Main Phases

The Gowan Lake pluton consists of quartz monzodiorite with subordinate monzodiorite and granodiorite. These rocks are characterized by considerable textural diversity arising from the variable development of late-magmatic microcline megacrysts as well as variation in grain size and crystal habit of amphibole. The compositional and textural variability of the main phases together with the heterogeneity introduced by abundant, variously assimilated mafic enclaves (discussed below) impart an extremely heterogeneous nature to the pluton as a whole.

Plagioclase is generally subhedral but in some cases is euhedral and exhibits a weakly porphyritic character. Plagioclase is generally andesine (An₄₂ to An₃₀) and individual crystals may be compositionally uniform or exhibit weakly developed normal zoning. Narrow, unaltered, albitic (An₆) rims are present on some crystals. One sample (7175) is characterized by highly unusual albitic (generally An₀ to An₉) compositions associated with extensive, patchy, k-feldspar replacement with minor preservation of (partially altered?) more calcic (up to An₂₅) plagioclase and is interpreted to reflect local, intense sub-solidus alteration. Microcline occurs both as interstitial, anhedral grains and as larger, poikilitic megacrysts up to several centimeters in diameter. In some samples, notably 7175, k-feldspar occurs as patchy or very fine-grained replacement of plagioclase.

The mafic mineralogy of the Gowan Lake pluton is relatively complex. Amphibole is the predominant mafic mineral and occurs both as stubby, equant crystals and acicular grains

that are rarely up to several centimeters in length. Based on microprobe analyses of a limited number of samples, the equant variety of amphiboles (samples 7183 and 7250) is somewhat more alkali-rich and less magnesian (edenite) than the acicular variety (7175 and 7233; magnesiohornblende). Amphiboles locally contain abundant, small, euhedral inclusions of magnetite, sphene, apatite and epidote. Minor clinopyroxene (diopside) occurs as cores in amphibole in several thin sections (Figure 18). Biotite (moderately to completely chloritized) is interpreted to be a primary mineral. Epidote is a common accessory mineral and much of this occurs as euhedral crystals that rarely display simple twinning and is interpreted to be a primary magmatic mineral phase.

Fe $\pm$ Ti oxides are an abundant (0.5 to 1.5 volume %) accessory constituent and their presence is interpreted to be responsible for the prominent aeromagnetic anomaly that is coincident with the Gowan Lake pluton. Oxides exhibit a range of compositions, textures and mineral associations. The most abundant variety is simple octahedra that are almost pure magnetite. These are interpreted to be an early magmatic phase based on their inclusion in euhedral amphibole and sphene (Figure 19). Less abundant, but still relatively common, are more complex oxide grains that contain 2 compositionally distinct oxide phases. The two phases are generally subordinate lamellae or blebs of ilmenite in a titanomagnetite host (Figure 19). These 2-phase grains are commonly, though not exclusively, closely associated with sphene. A third, volumetrically minor mode of occurrence of Fe-Ti oxides is as platy grains that are parallel to and within cleavage planes of biotite, particularly where the later is chloritized.

Other primary magmatic minerals include sphene, epidote, apatite and zircon. Apatite, in particular, is an anomalously abundant accessory mineral with respect to its abundance in other granitoid rocks associated with the Hemlo greenstone belt.

The rocks are commonly relatively fresh with minor chloritization of biotite and saussuritization of plagioclase feldspar but these styles of alteration are locally relatively intense. This alteration is interpreted to be a deuteric phenomenon.

Sharply to diffusely bounded mafic enclaves are a widespread minor component of the pluton and are distinguished mineralogically from the host primarily by higher color index and greater abundance of k-feldspar (Figures 3 and 4). A limited number of mafic enclaves examined in detail have generally similar mineral relationships as described for the host rocks except for absence of clinopyroxene and lesser abundance of simple magnetite octahedra.

Geochemical Characteristics

The Gowan Lake pluton has geochemical characteristics that distinguish it from most other plutons associated with the Hemlo greenstone belt. The relatively quartz-poor nature and amphibole-dominated mafic mineralogy are reflected in its distinctly metaluminous character and low SiO₂. The pluton is calc-alkaline like others in the Hemlo area but has a transitional alkaline to subalkaline nature (Figure 20). Equigranular and megacrystic phases generally define single, coherent trends that vary with SiO₂ as

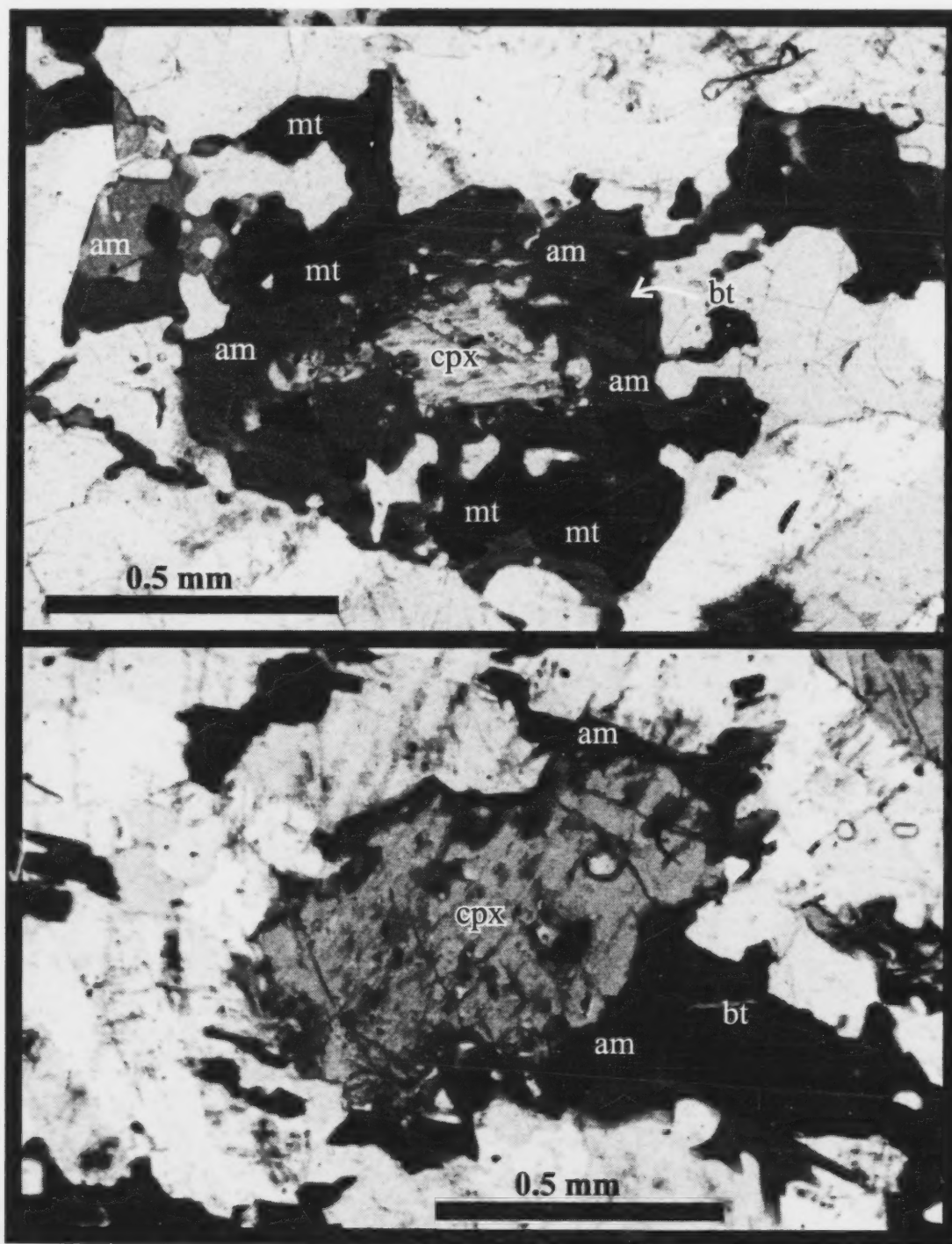


Figure 18. Photomicrographs illustrating the textural relationships between ferromagnesian minerals (cpx= clinopyroxene; am= amphibole; bt=biotite; mt= magnetite) in the Gowan Lake pluton. Clinopyroxene is invariably rimmed by amphibole and both commonly contain abundant small inclusions of a single phase oxide (magnetite) and apatite. Both photos taken in plane polarized light.

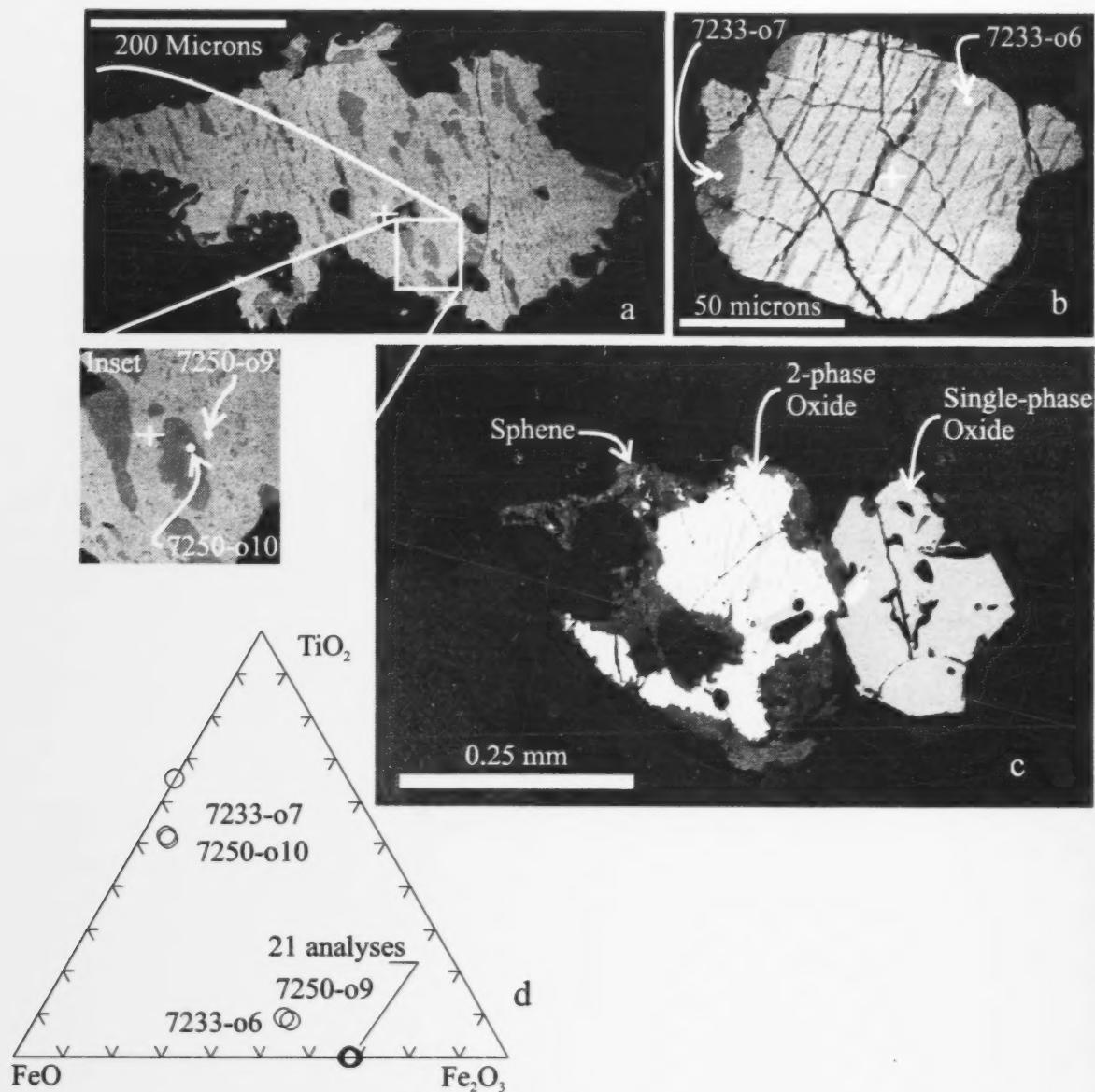


Figure 19. Oxide mineralogy of the Gowan Lake pluton. 19a electron backscatter image with inset illustrates complex oxide (ilmenite blebs in titanomagnetite host) grain rimmed by sphene. 19b electron backscatter image illustrating a sphene rimmed complex oxide grain with lamellar ilmenite within titanomagnetite host. 19c reflected light photomicrograph illustrating the coexistence of single- and 2-phase oxide grains. 19d ternary plot illustrating the composition of Gowan Lake pluton oxide phases with FeO and Fe_2O_3 estimated from total iron and charge balance considerations.

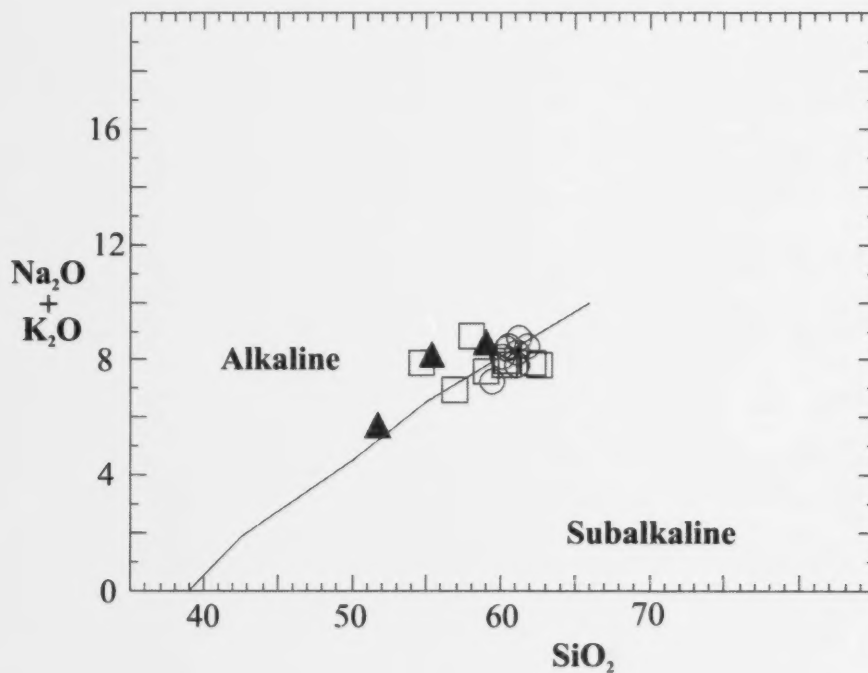
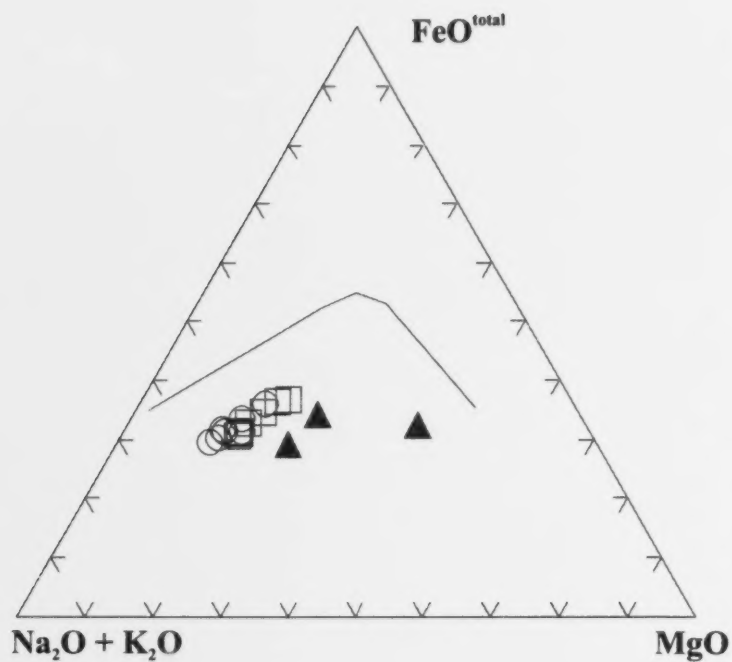


Figure 20. AFM and total alkali - SiO_2 classification diagrams (Irvine and Baragar, 1971) illustrating the calc-alkaline and transitional subalkaline to alkaline nature of the Gowan Lake pluton. Circles= equigranular samples; Squares= microcline megacrystic samples; Filled triangles= enclaves.

expected although the megacrystic variety tend to have higher Ni, Cr and Mg# than the equigranular variety (Figure 21). Three samples of mafic enclaves are strongly metaluminous and depart significantly from the trends displayed by the main phases for Al_2O_3 , TiO_2 , MgO , Na_2O , K_2O , Mg#, Ni and Cr (Figure 21).

The main phases have relatively abundant HFSE and REE are abundant and generally display only moderate fractionation with weak negative Eu anomalies. The equigranular and megacrystic varieties have similar REE patterns with $\text{Ce}_\text{N}/\text{Yb}_\text{N} \sim 12\text{-}20$ and $\text{Yb}_\text{N} \sim 10\times$ chondrite (Figure 22). Mafic enclaves have similar middle and heavy REE as compared to the main phases but are much more variable in their LREE abundances and have a distinctive concave down LREE profile (Figure 22). The concave down LREE profile may be indicative of accumulation of a mineral phase (clinopyroxene, amphibole or apatite; Hanson, 1978) that rejects the LREE relative to the middle and heavy REE.

Despite their relatively primitive character suggested by low SiO_2 and high MgO and FeO , the main phases of the pluton have relatively abundant LILE ($\text{K}_2\text{O} \sim 3\text{-}4\%$; $\text{Rb} \sim 70\text{-}130$ ppm) and low $\text{Na}_2\text{O}/\text{K}_2\text{O}$ ratio. This dichotomy is even more pronounced for the mafic enclaves.

The Nd isotopic signature of the Gowan Lake pluton ($\epsilon_\text{Nd} = +1.7$ to $+1.9$) is slightly less radiogenic than most estimates of Archean depleted mantle.

Petrogenetic Interpretation

The Gowan Lake pluton is unlikely to be derived from the partial melting of, or significantly contaminated by, preexisting intermediate to felsic igneous rocks or metasedimentary rocks for a number of reasons. Such rocks, as well as their probable melting residues, do not occur as inclusions in the Gowan Lake pluton. The relatively mafic nature of the pluton would require either a high degree of melting of unusually mafic crust or that the pluton consist largely of mafic cumulate phases. The elevated LILE abundances would be inconsistent with either of these unlikely hypotheses. The probable residual mineralogy for melting of upper crustal lithologies are all unlikely to be significant components in the source material for the Gowan Lake pluton. Residual plagioclase would result in prominent negative Eu anomalies and Ca and Sr depletion, none of which is observed. Both garnet and amphibole would deplete the melt in HREE and their presence in the residue would be incompatible with observed HREE abundances and melting of typical upper crustal compositions.

The melting of mafic (basaltic) crust to form intermediate magmas (TTG model) is also considered unlikely. Relative to model melts of tholeiitic basalt and empirical characteristics of rocks of inferred TTG origin, the Gowan Lake pluton is different in a number of important respects. The relatively mafic, mildly alkaline, LILE-rich nature of the Gowan Lake pluton is atypical of TTG magmas. The LILE-rich character could be explicable if a basaltic source underwent low degrees of melting but this would not be consistent with the mafic nature, which would require higher degrees of melting. Most residual mineral assemblages for partial melting of basaltic crust would include a

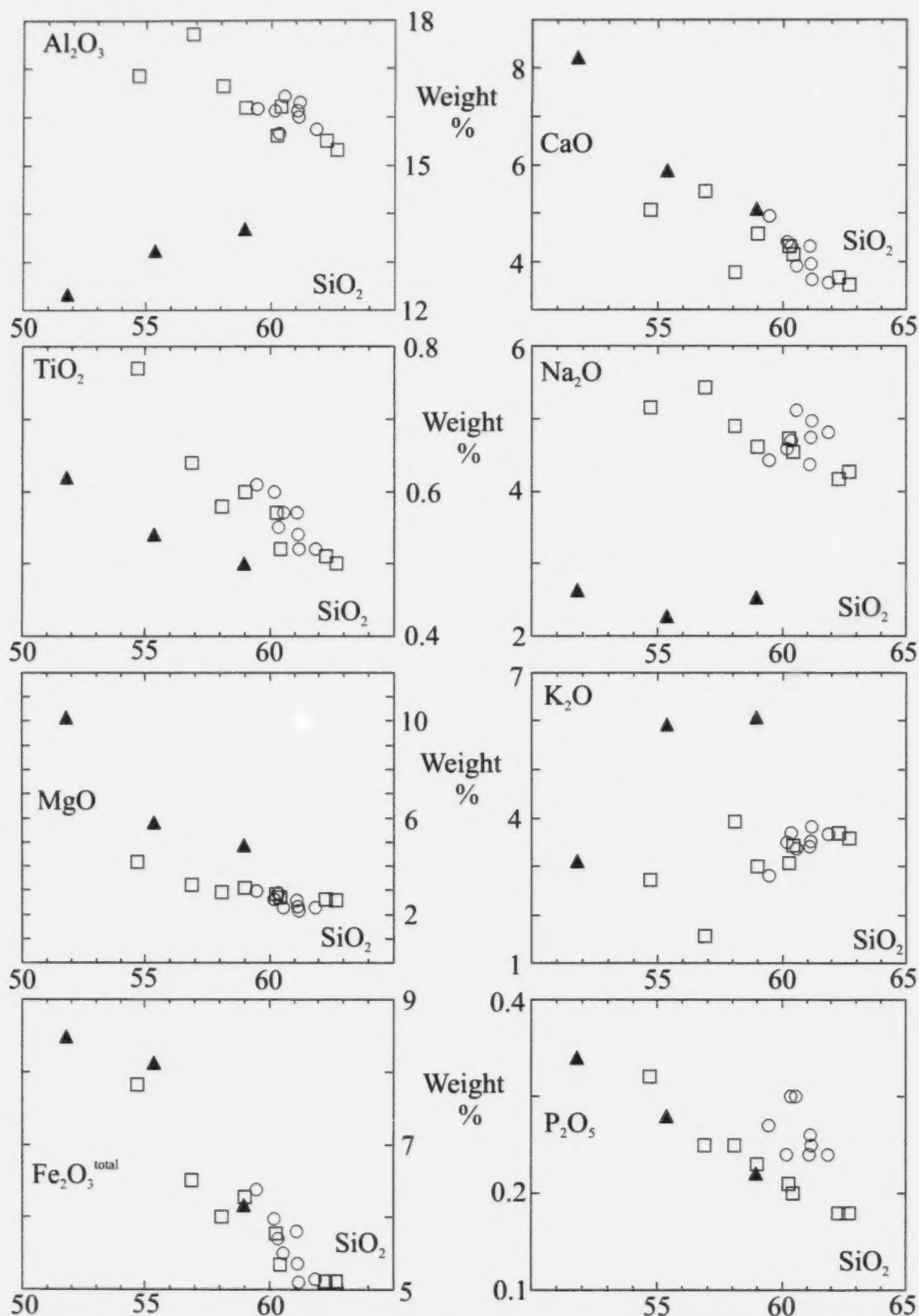


Figure 21a. Harker variation diagrams for the Gowen Lake pluton. Circles= equigranular samples; Squares= microcline megacrystic samples; Filled triangles= enclaves.

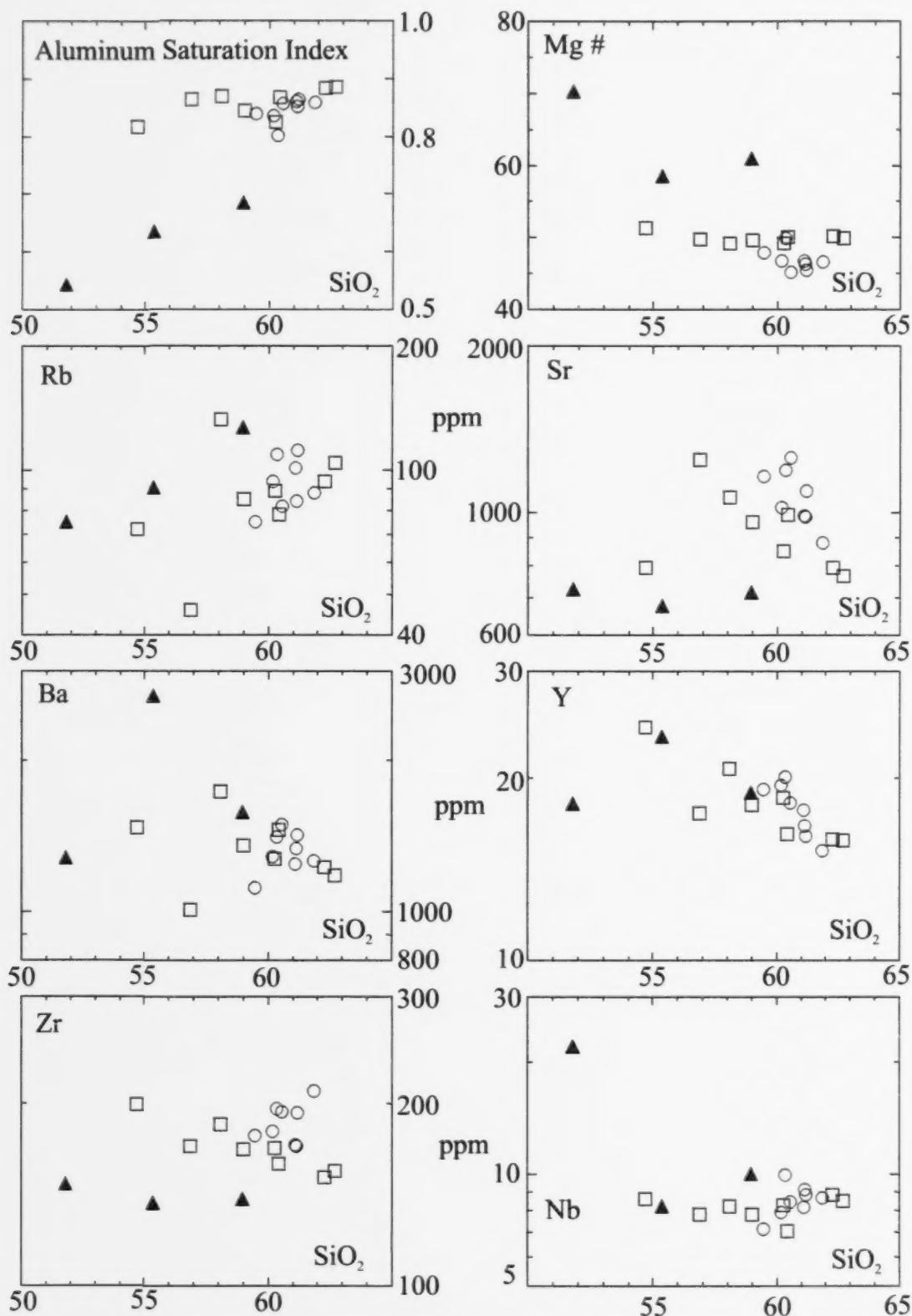


Figure 21b. Harker variation diagrams for the Gowen Lake pluton. Circles= equigranular samples; Squares= microcline megacrystic samples; Filled triangles= enclaves.

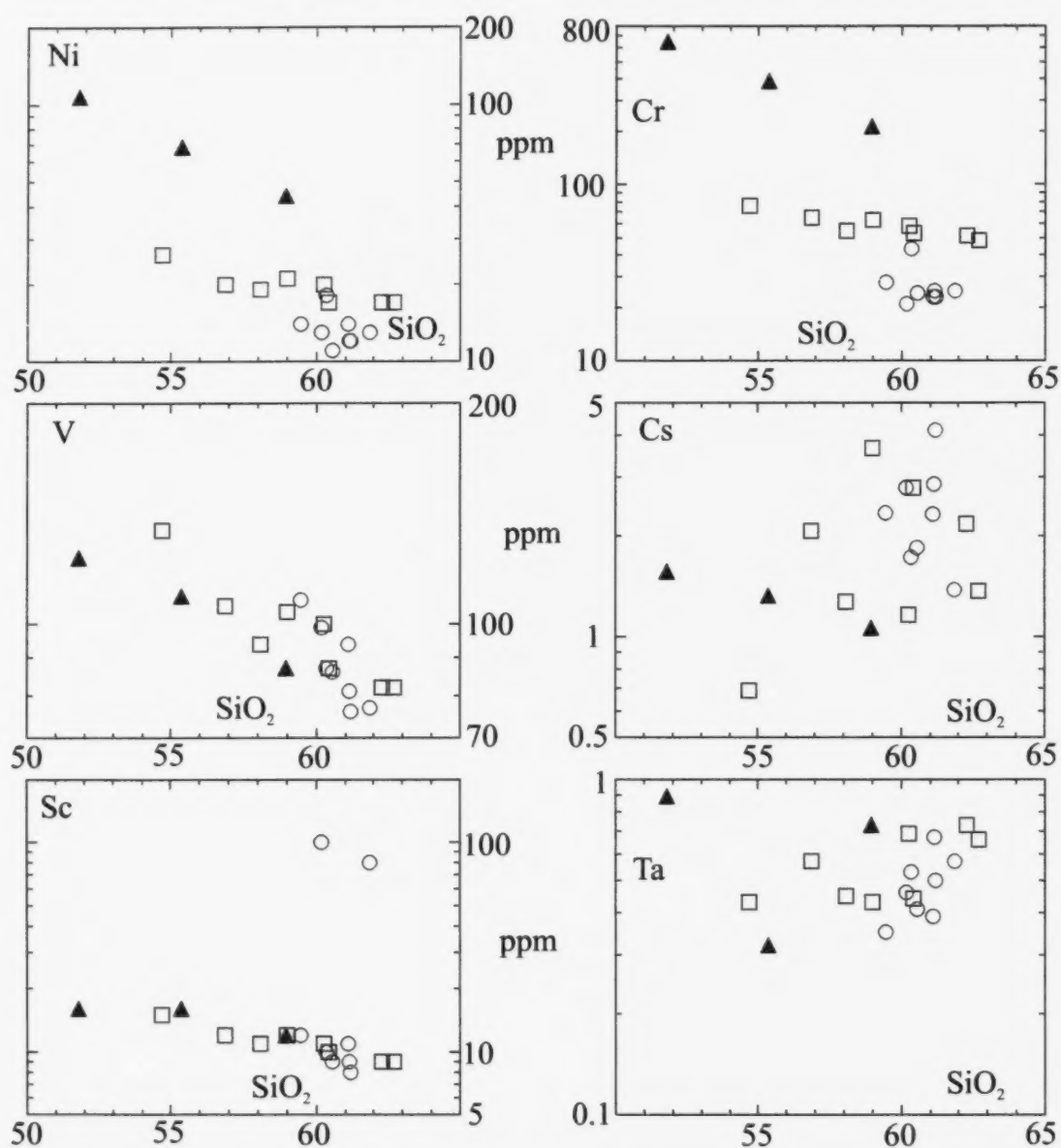


Figure 21c. Harker variation diagrams for the Gowan Lake pluton. Circles= equigranular samples; Squares= microcline megacrystic samples; Filled triangles= enclaves.

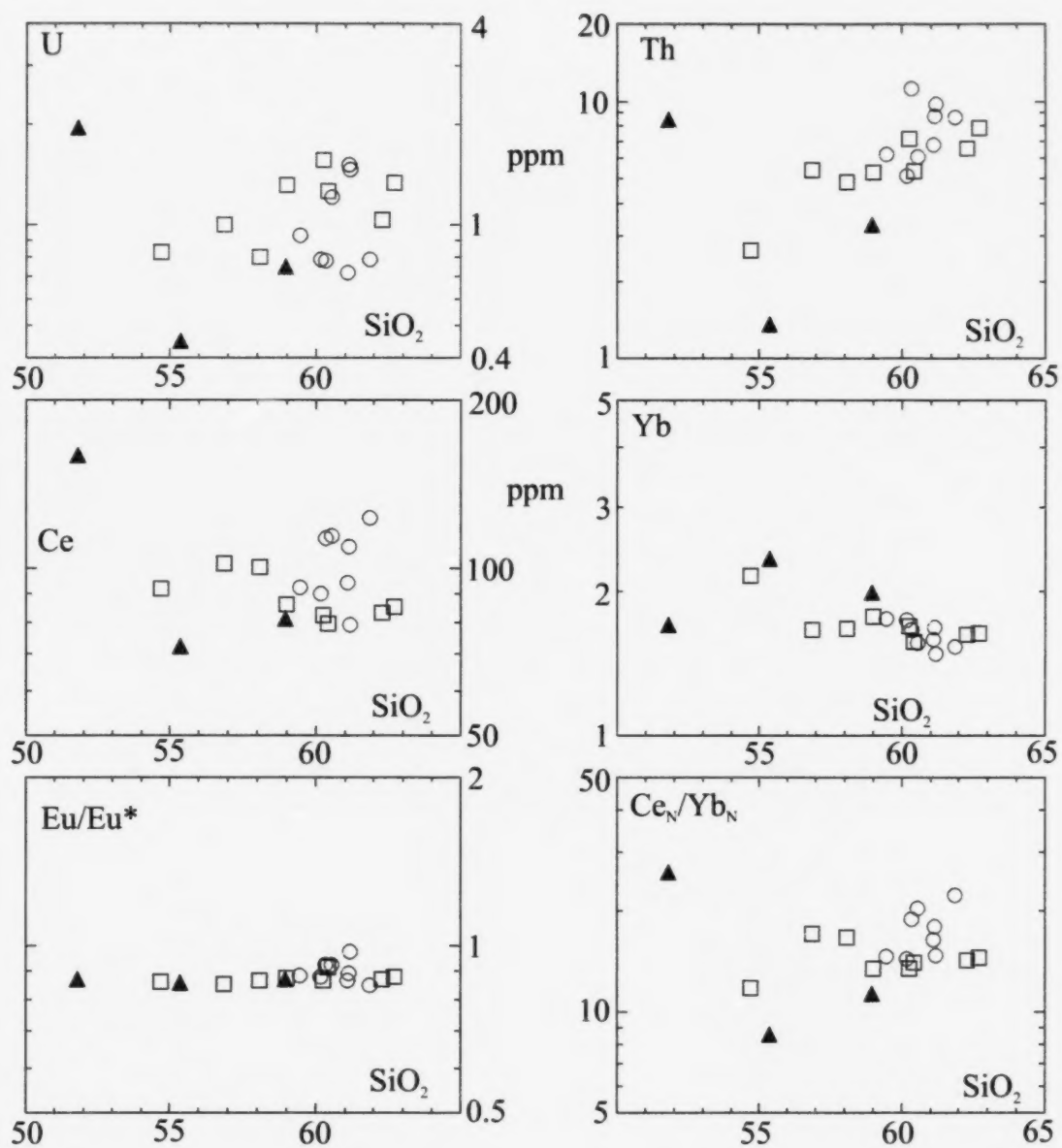


Figure 21d. Harker variation diagrams for the Gowan Lake pluton. Circles= equigranular samples; Squares= microcline megacrystic samples; Filled triangles= enclaves.

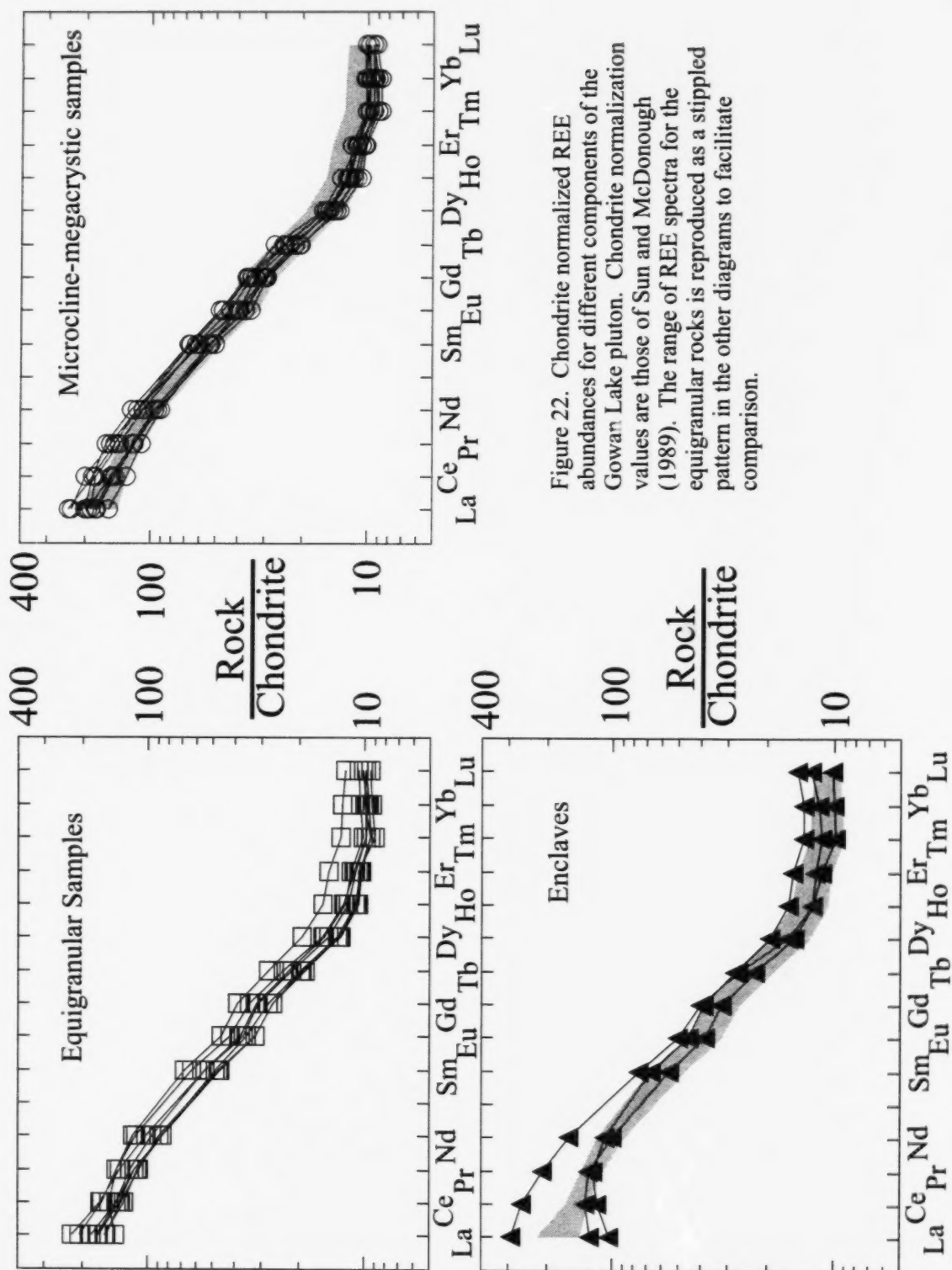


Figure 22. Chondrite normalized REE abundances for different components of the Gowen Lake pluton. Chondrite normalization values are those of Sun and McDonough (1989). The range of REE spectra for the equigranular rocks is reproduced as a stippled pattern in the other diagrams to facilitate comparison.

significant amount of garnet and/or amphibole, which would result in HREE depletion. The relatively high HREE abundances of the Gowan Lake pluton (~10x chondrite) would only be explicable in the TTG model if neither garnet nor amphibole were residual minerals or the source had a highly unusual REE-rich character. The high LREE abundances (~200x chondrite) are also unusual for magmas of inferred TTG affinity.

The characteristics of the Gowan Lake pluton are most comparable to those reported for members of a suite of mantle-derived (sanukitoid) magmas (Shirey and Hanson, 1984). The Mg# and Ni and Cr abundances of the main phases of Gowan Lake pluton are lower than those considered characteristic of primary sanukitoid magmas and if this model is correct, the pluton must represent more fractionated members of the suite rather than direct mantle melts. The enclaves have similar Mg#, Ni and Cr to primary sanukitoid magmas but this observation must be tempered by the possibility that the enclaves may be, in part, cumulate phases. The elevated, fractionated REE abundances and the elevated LILE abundances reflect the enrichment of these elements in the metasomatized mantle source. The Nd isotope characteristics of the Gowan Lake pluton are intermediate between that of depleted and undepleted mantle and require that if this model is correct, the metasomatism could not have preceded the melting event by more than 50-100 Ma.

Despite the inherent difficulty in developing a model that involves a poorly constrained intermediate stage (metasomatism), the sanukitoid model is considered to provide the most reasonable explanation for the dual primitive / evolved nature of the Gowan Lake pluton. The strongly metaluminous, mafic character of the pluton together with elevated Mg#, Ni and Cr reflect the ultramafic parentage whereas the high LILE and REE abundances reflect the metasomatized nature of the source.

Cedar Creek Stock and Satellite Stock

The Cedar Creek and Satellite stocks occur near each other, are both characterized by a prominent aeromagnetic anomaly and share many of the same petrographic and geochemical characteristics. This close association and similar characteristics suggests that the two units are genetically related and they are consequently discussed together.

The Cedar Creek stock is characterized by a uniform granodioritic composition (Figure 3) and a low color index with biotite predominating over hornblende (Figure 4). The stock also has a uniform medium grained, hypidiomorphic equigranular texture except near the margin where it is somewhat finer grained. One sample contained optically continuous, intergranular microcline that may represent incipient megacryst formation.

Plagioclase is subhedral and displays weak oscillatory to normal zoning with all microprobe determinations in the range An_{30} to An_{20} (average of 11 analyses is An_{25}). Alteration to a fine grained assemblage of white mica, epidote and carbonate is variable from sample to sample and within individual thin sections but is generally patchy and only weakly to moderately developed. Microcline is a relatively late intergranular phase that is fresh and has a uniform composition of approximately $Or_{95}Ab_5$. Quartz is intergranular with respect to plagioclase and mafic minerals and has undulose extinction.

Biotite is the predominant primary mafic mineral and is either fresh or displays weak alteration to chlorite. Amphibole (average magnesiohastingsite) is a fresh, early (subhedral to euhedral) primary mineral.

Sphene is a relatively abundant accessory mineral that is interpreted to be an early crystallizing phase on the basis of its subhedral to euhedral habit where it occurs within biotite and amphibole crystals. Epidote occurs mostly as granular masses of uncertain origin but a small percentage of crystals display euhedral form and simple twinning suggesting that it is, at least in part, an early primary magmatic phase. Subhedral to euhedral magnetite is relatively abundant and accounts for the prominent aeromagnetic anomaly associated with the Cedar Creek stock. Other primary accessory minerals include apatite and zircon. Minor amounts of sulphide and carbonate occurring in several samples are interpreted to reflect minor secondary alteration.

The Satellite stock is poorly exposed and the nature and proportions of different components is poorly understood. Two granodioritic samples, presumed to be the main component of the stock, have a higher proportion of plagioclase and different proportions of amphibole and biotite but exhibit general petrographic similarity to the Cedar Creek stock. A single sample of a dioritic phase (extent and mode of occurrence unknown) has a hornblende-dominated quartz monzodioritic composition similar to the dioritic enclaves in the Cedar Lake and Gowan Lake plutons (Figure 3).

Geochemical Characteristics

Whole rock geochemistry of the Cedar Creek stock also indicates a very uniform composition. These rocks are weakly metaluminous with 67-69% SiO_2 and low Mg# (38-41). High Na_2O , Na/K and low CaO relative to other plutons in the Hemlo greenstone belt area are also distinctive characteristics. REE are highly fractionated with near chondritic HREE and negligible Eu anomalies. A single sample returned a depleted mantle-type isotopic signature ($\epsilon_{\text{Nd}} = +2.1$).

The geochemical characteristics of the granodioritic phase of the Satellite stock closely resembles that of the Cedar Creek stock. The single quartz monzodioritic sample is relatively primitive in terms of SiO_2 , TiO_2 , Mg#, Ni and Cr yet it has relatively high abundances of K_2O , Rb, Cs, Zr, Th and U. In these respects, it is similar to dioritic components within the Cedar Lake and Gowan Lake plutons.

Among the main phases of the plutons discussed above, the Cedar Creek stock and granodioritic components of the Satellite stock most closely resembles the higher SiO_2 samples of the Heron Bay pluton (Figures 23 to 37) although the former is characterized by lower MgO, Mg# and Ni and higher Ce and Ce_N/Yb_N than the latter. The geochemical characteristics of the Cedar Creek and Satellite stock granodiorites are closely comparable to those of the magnetic granodiorite phase of the Cedar Lake pluton (Figure 38). Like the magnetic granodiorite phase, the Cedar Creek stock differs from the main phase of the Cedar Lake pluton in having higher SiO_2 and lower MgO, Mg#, Ni and Cr.

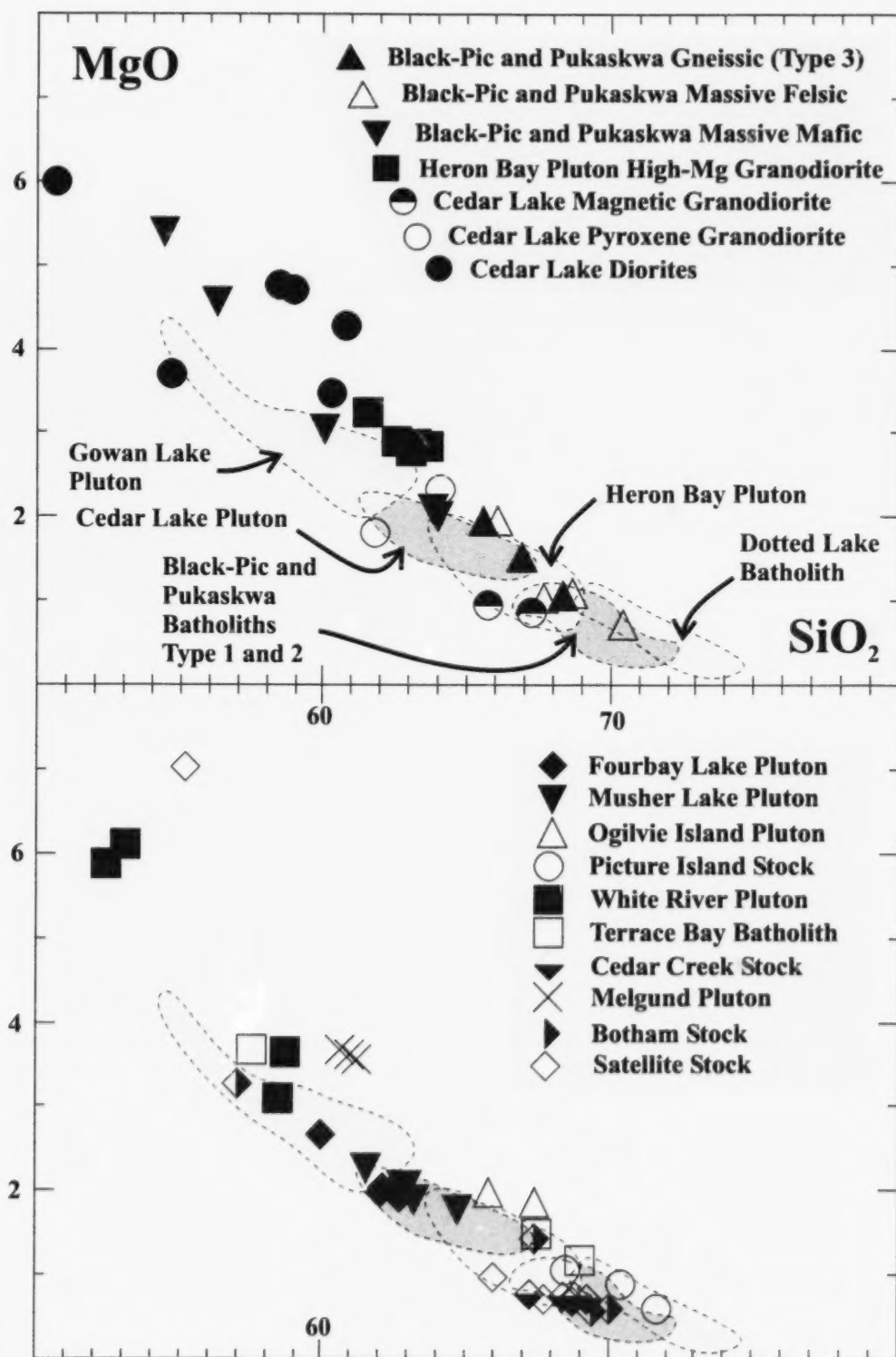


Figure 23. Plot of MgO vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

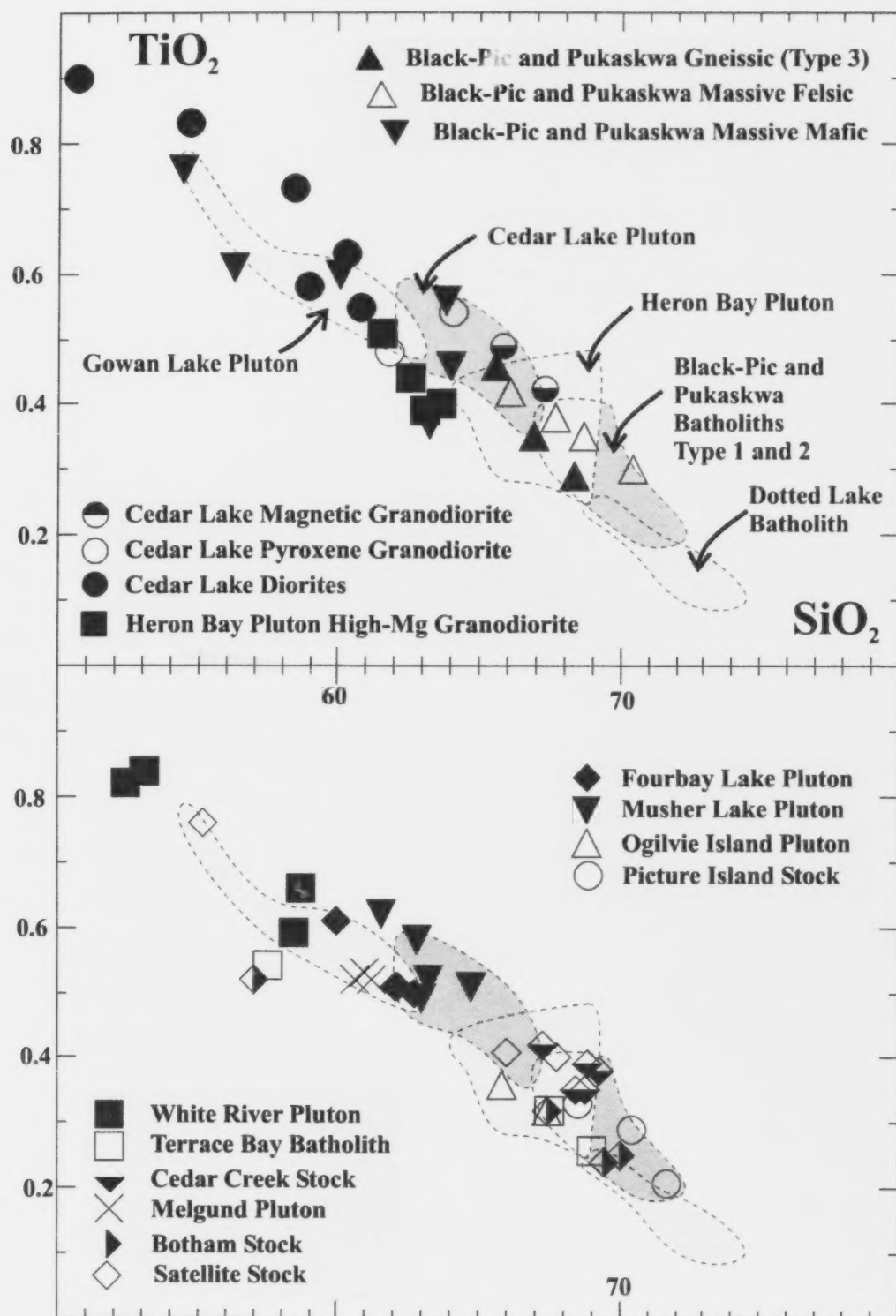


Figure 24. Plot of TiO₂ vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

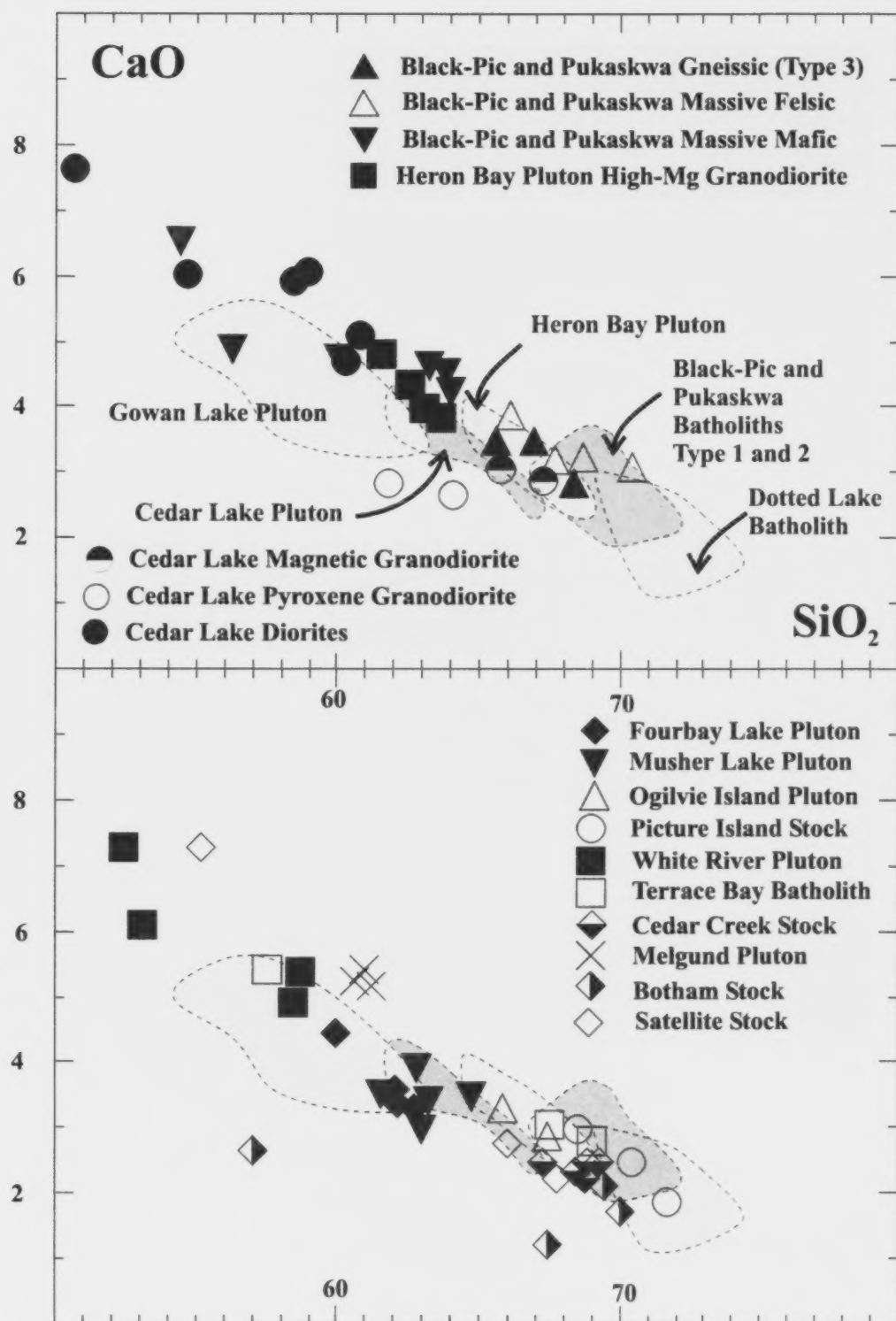


Figure 25. Plot of CaO vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

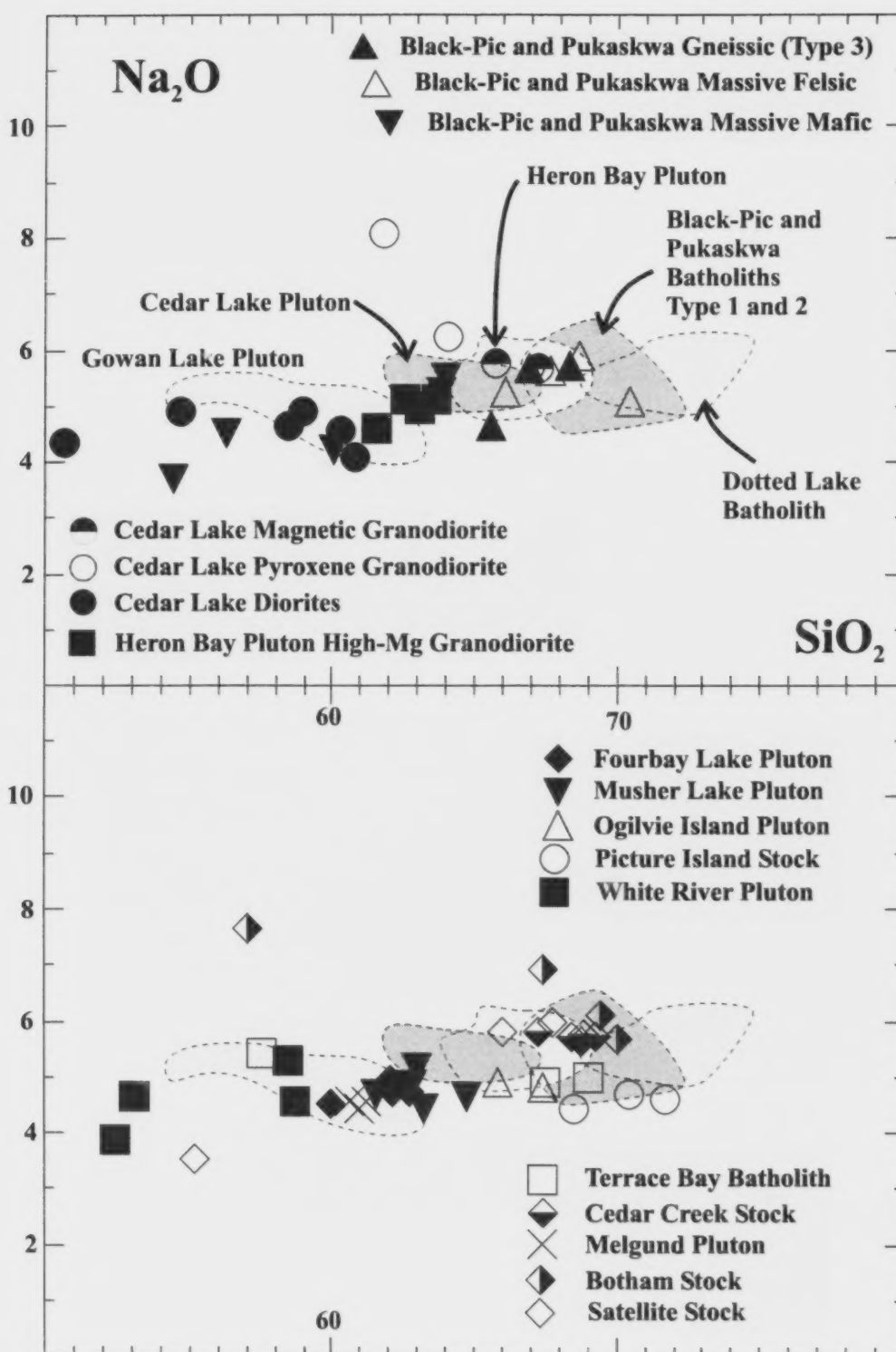


Figure 26. Plot of Na₂O vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

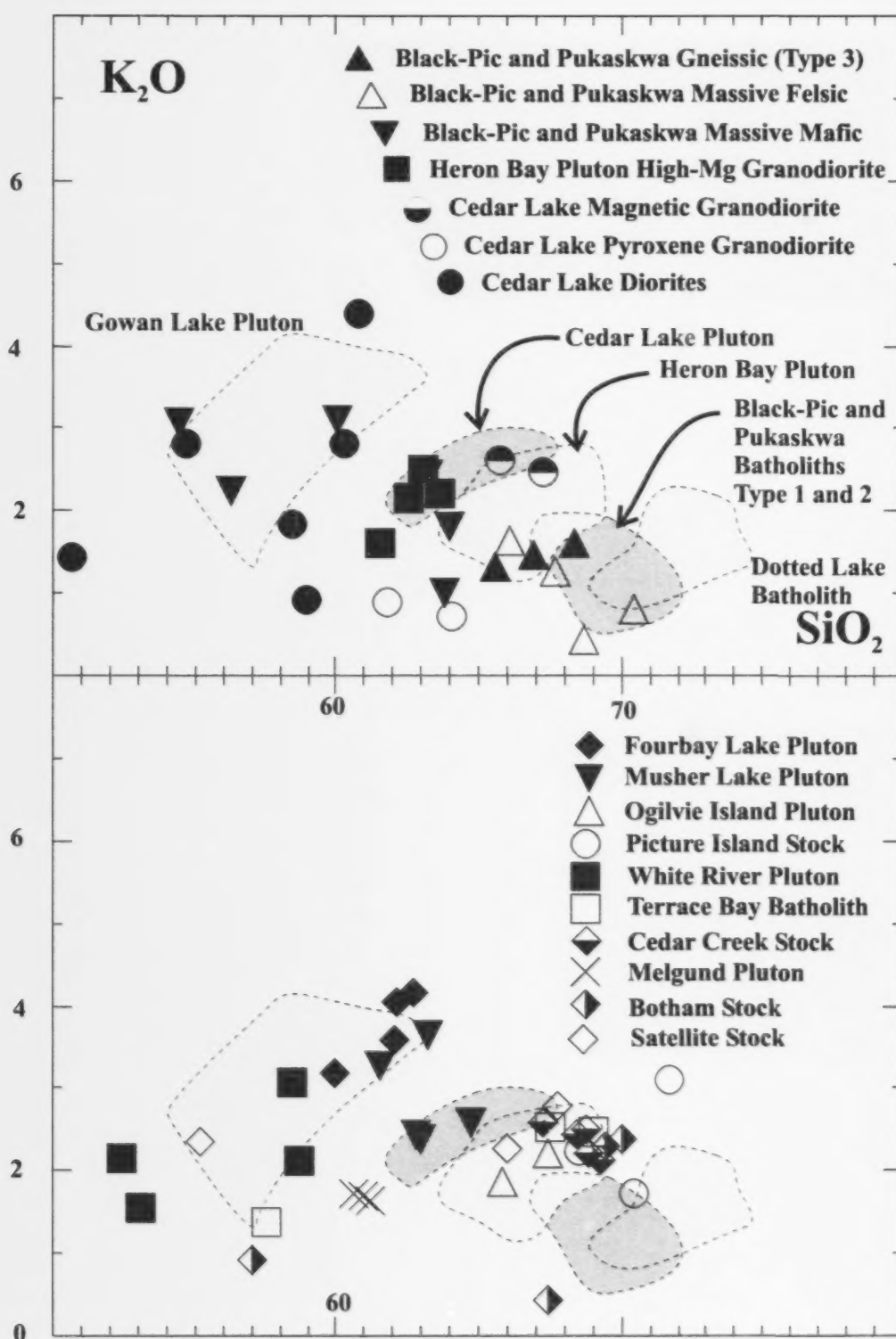


Figure 27. Plot of K_2O vs SiO_2 comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

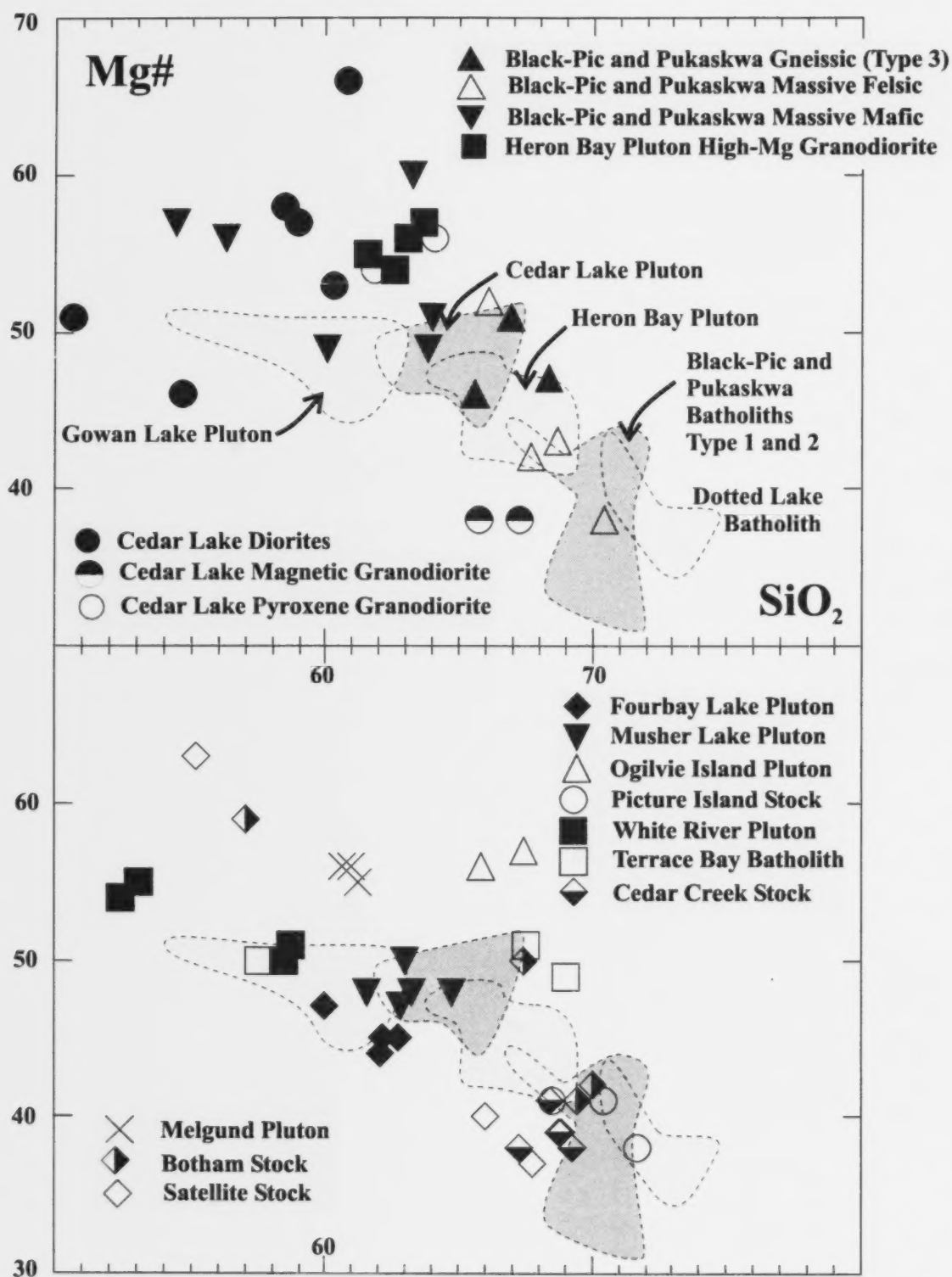


Figure 28. Plot of Mg number vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

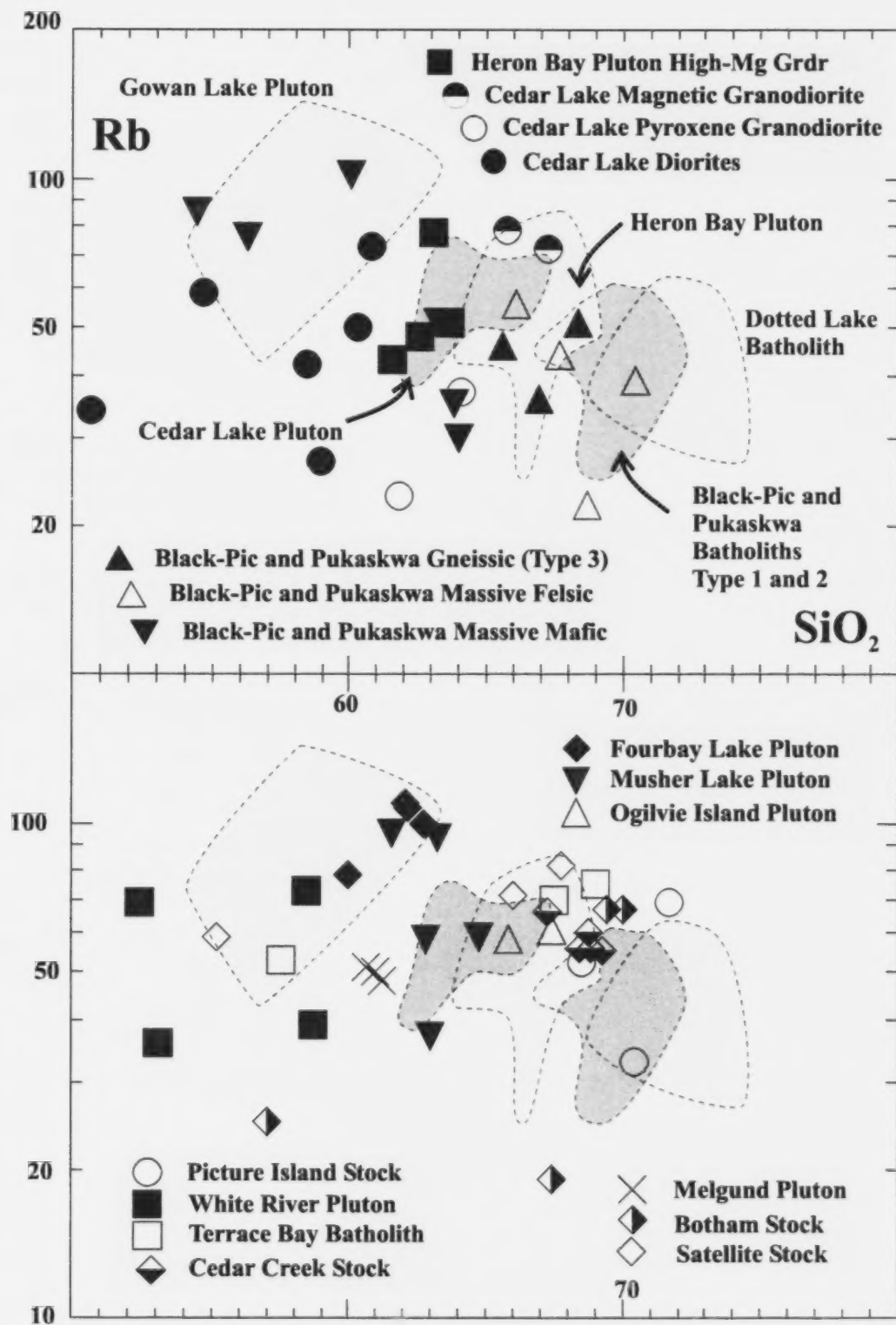


Figure 29. Plot of Rb vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

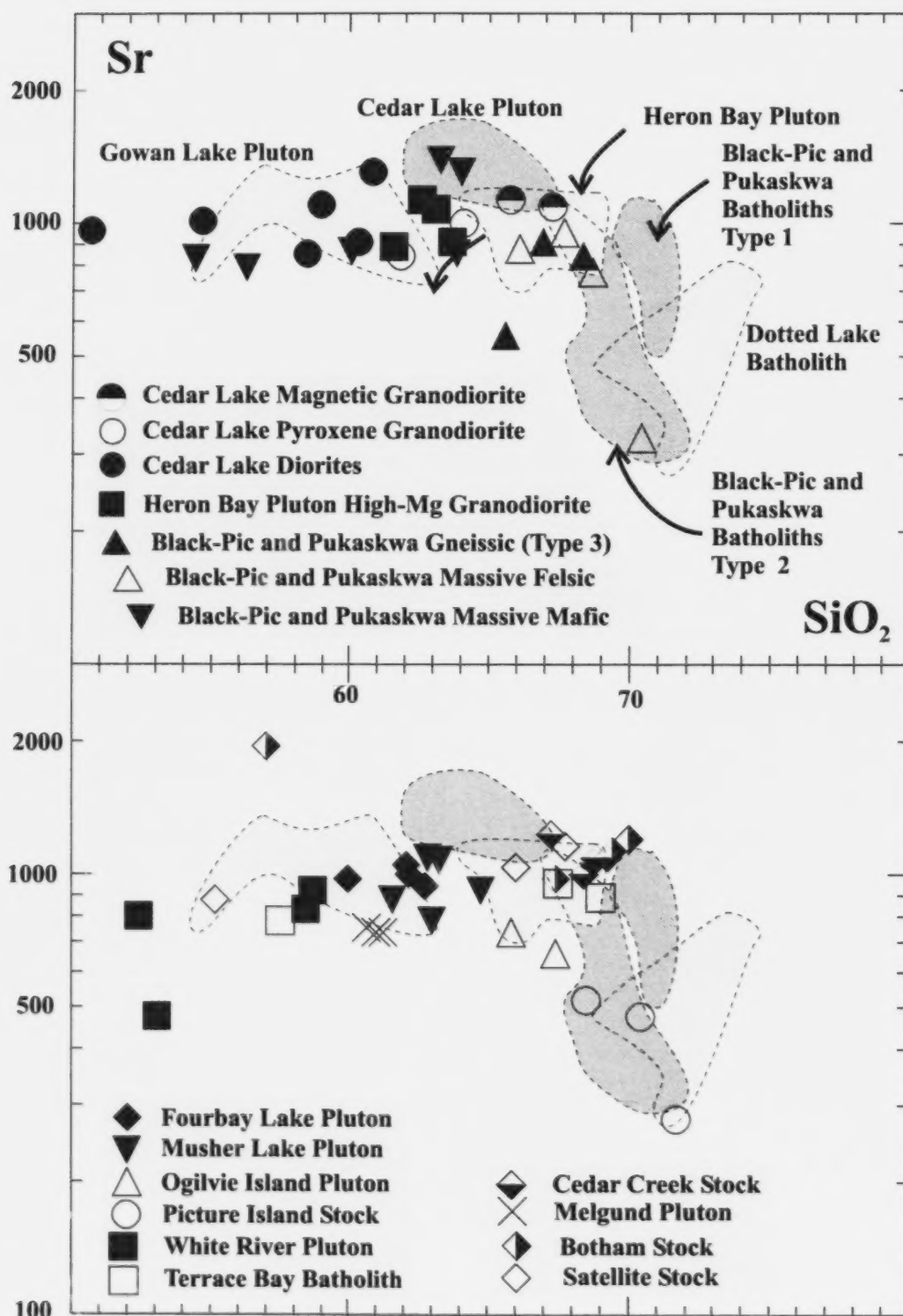


Figure 30. Plot of Sr vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

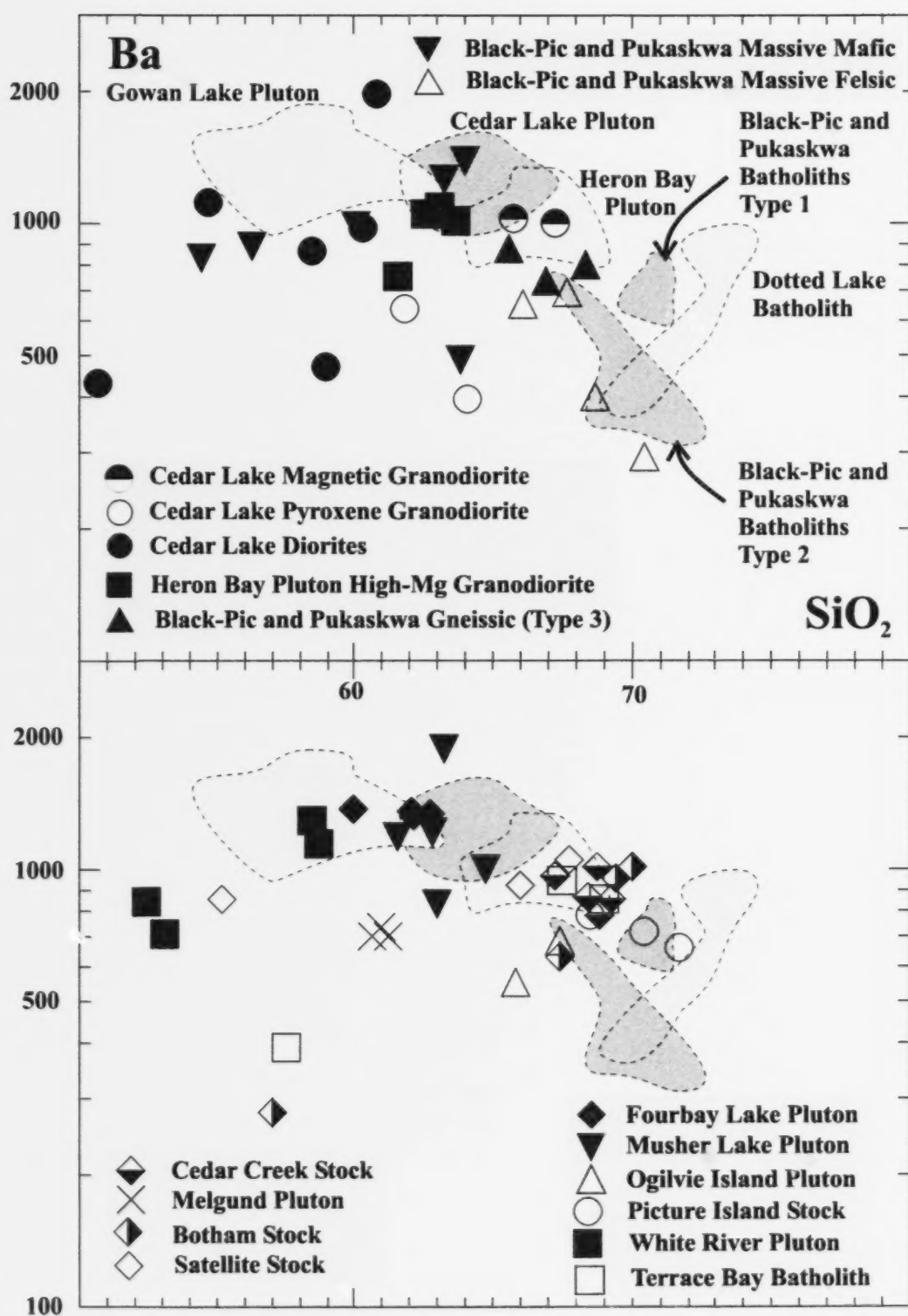


Figure 31. Plot of Ba vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

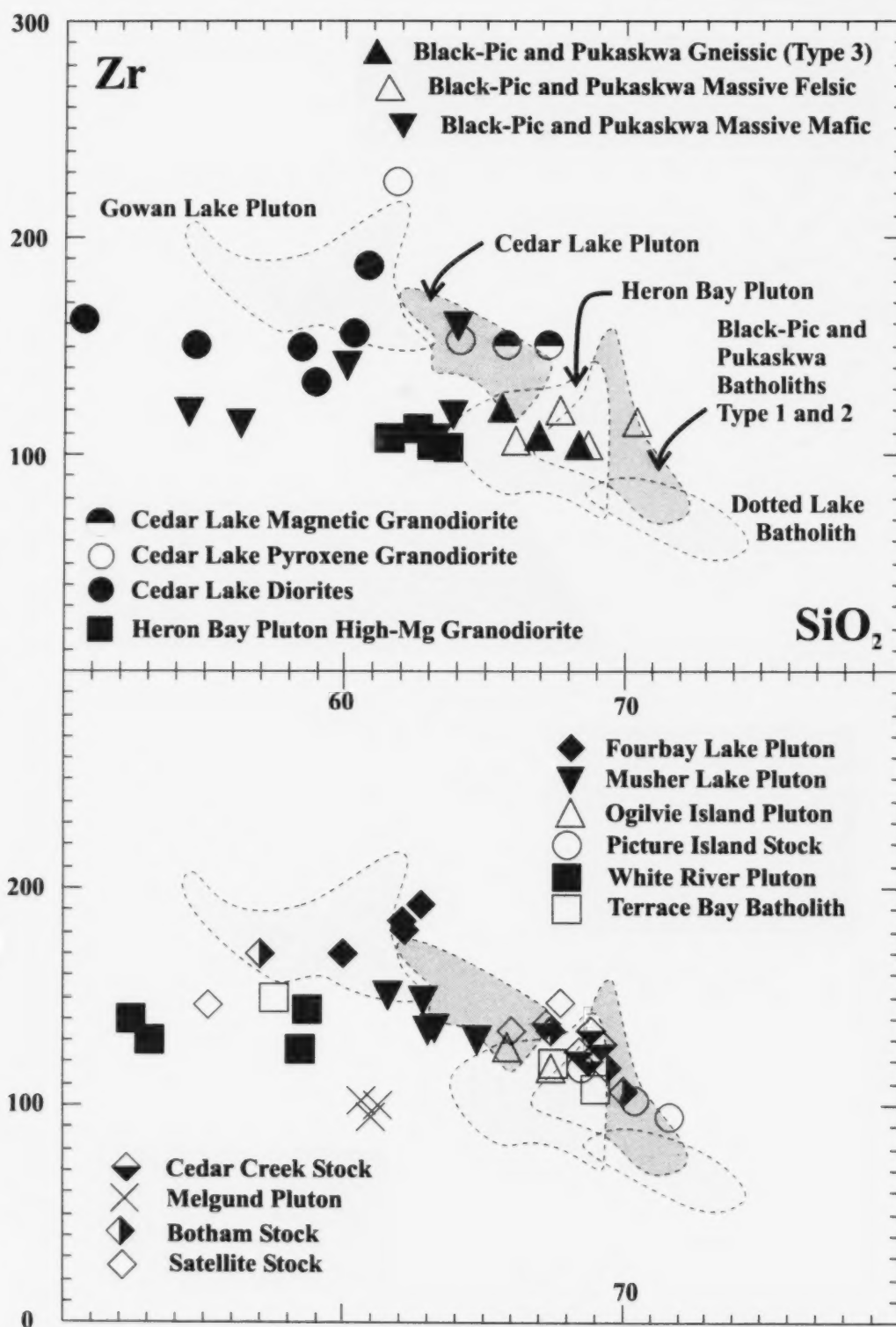


Figure 32. Plot of Zr vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

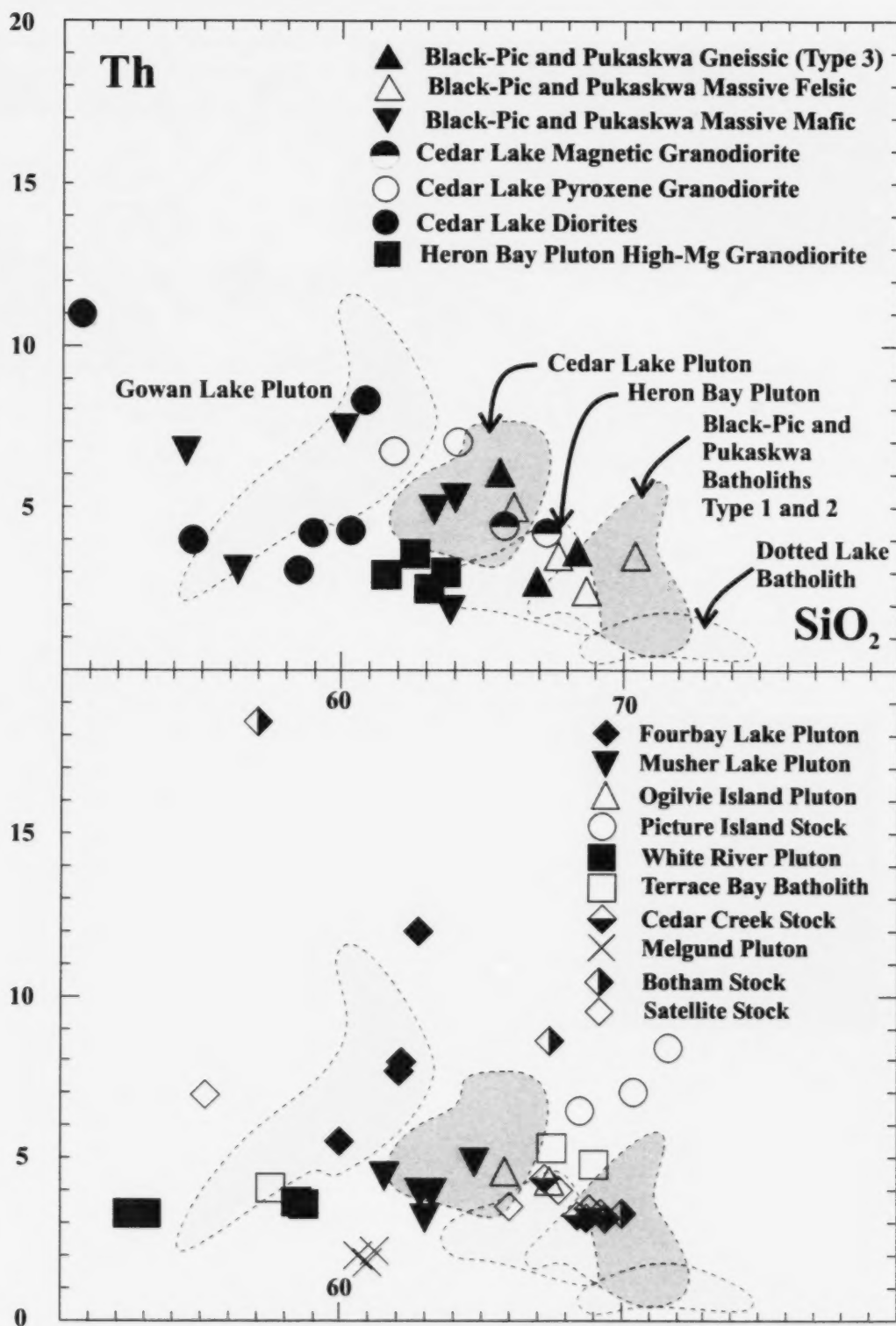


Figure 33. Plot of Th vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

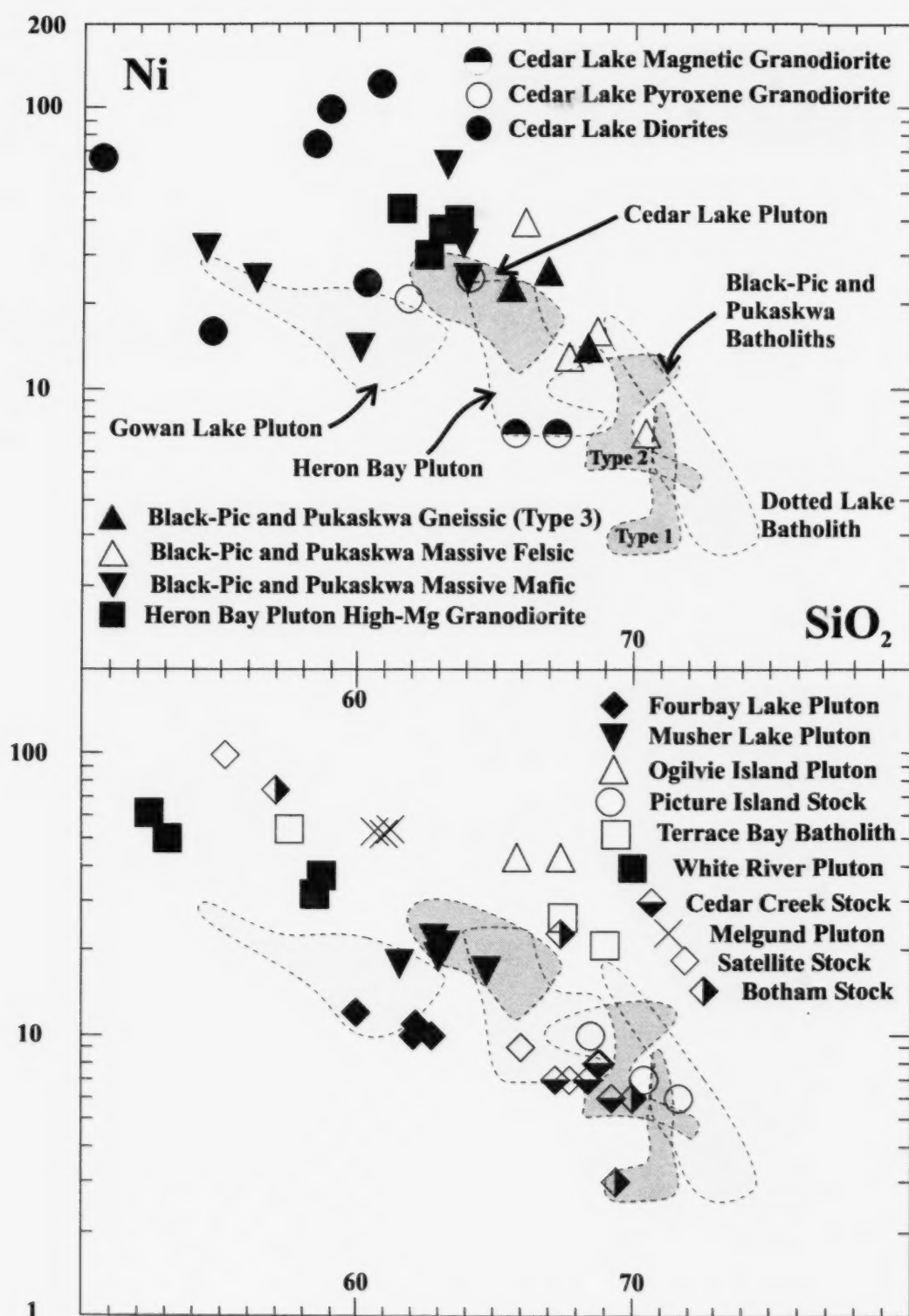


Figure 34. Plot of Ni vs SiO₂, comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

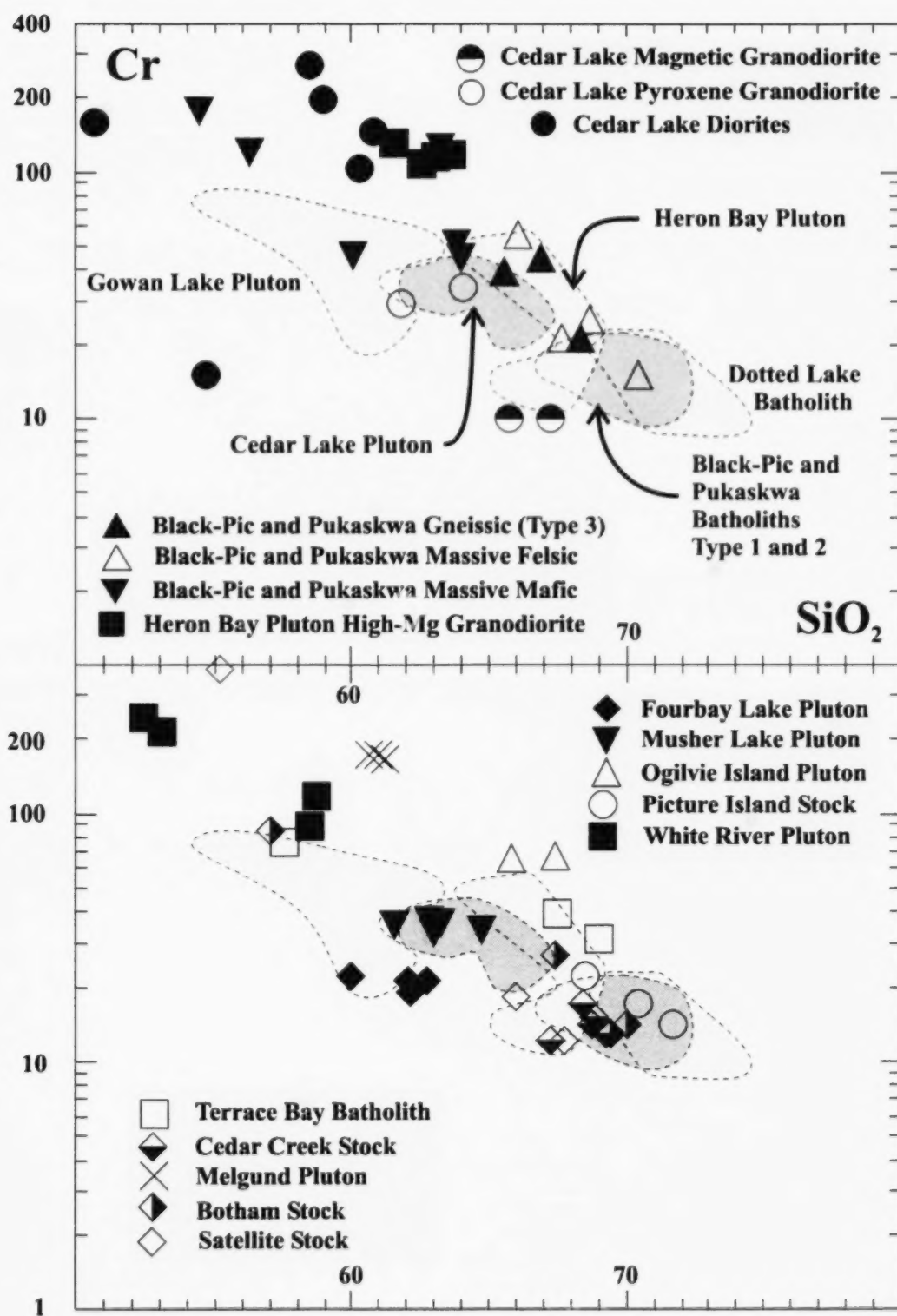


Figure 35. Plot of Cr vs SiO_2 comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

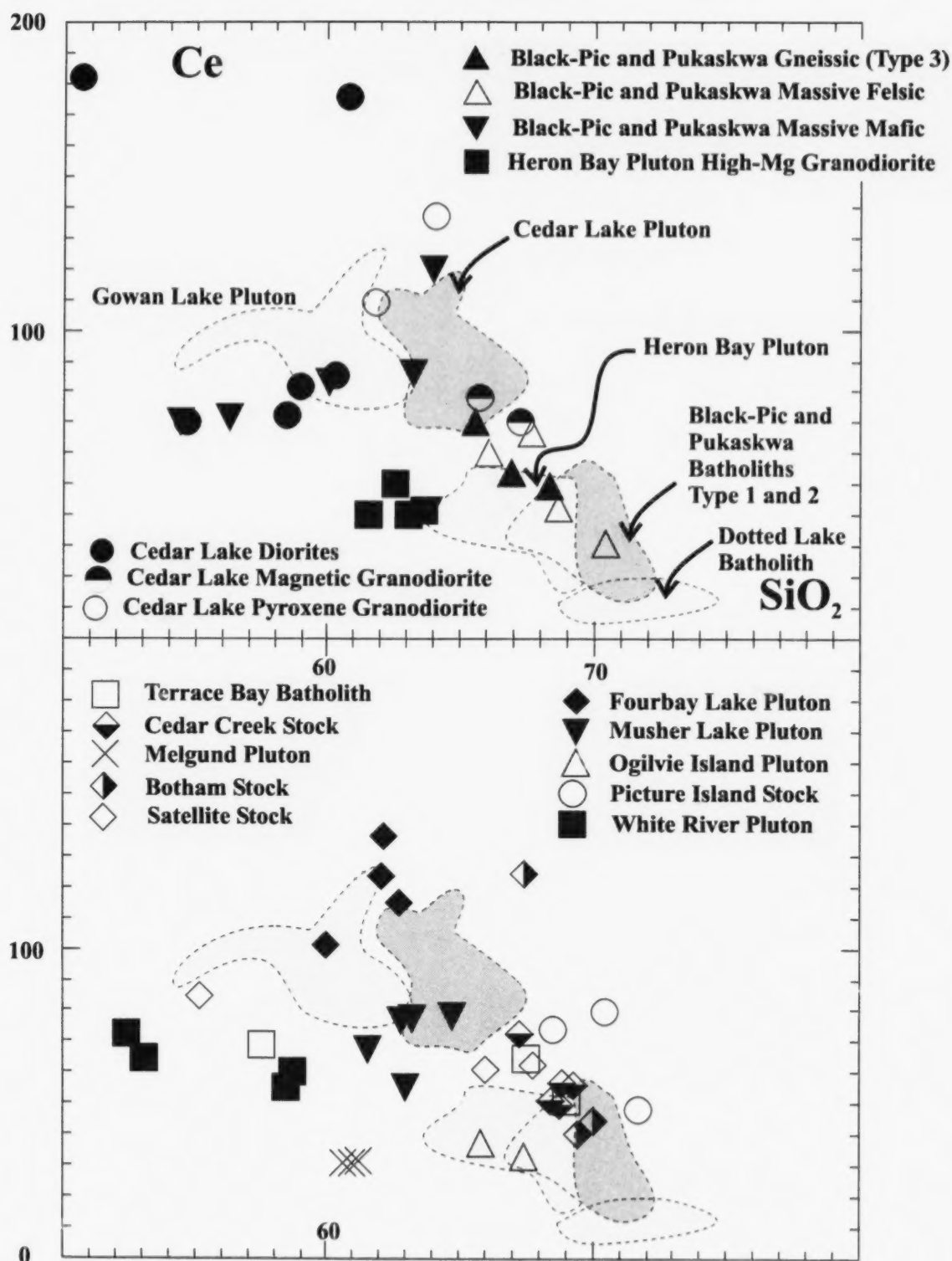


Figure 36. Plot of Ce (ppm) vs SiO_2 (weight %) comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

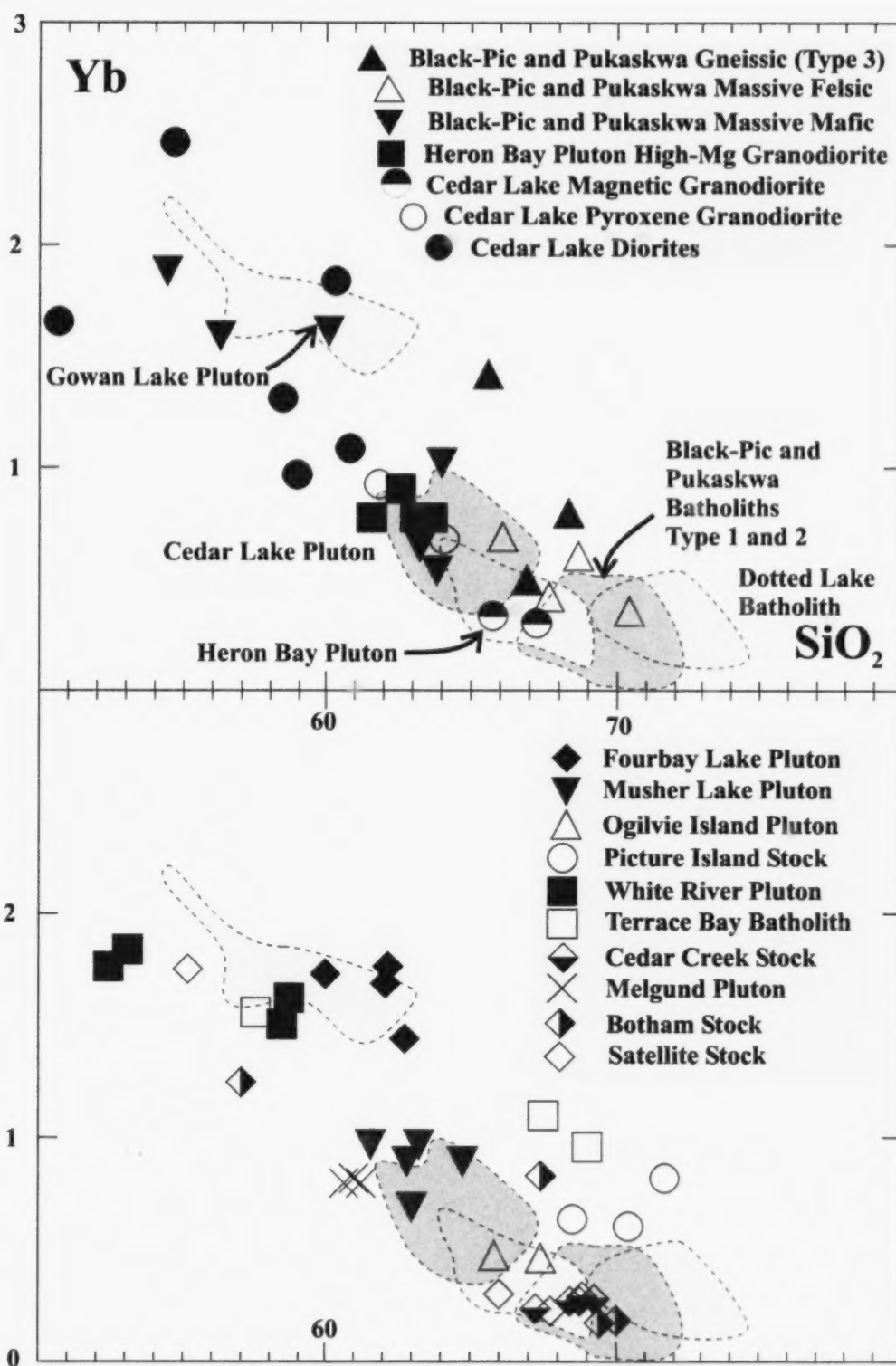


Figure 37. Plot of Yb vs SiO₂ comparing the compositions of minor associated phases (above) and minor discrete plutons (below) with those of the main phases of the major granitoid units (shaded areas) associated with the Hemlo greenstone belt.

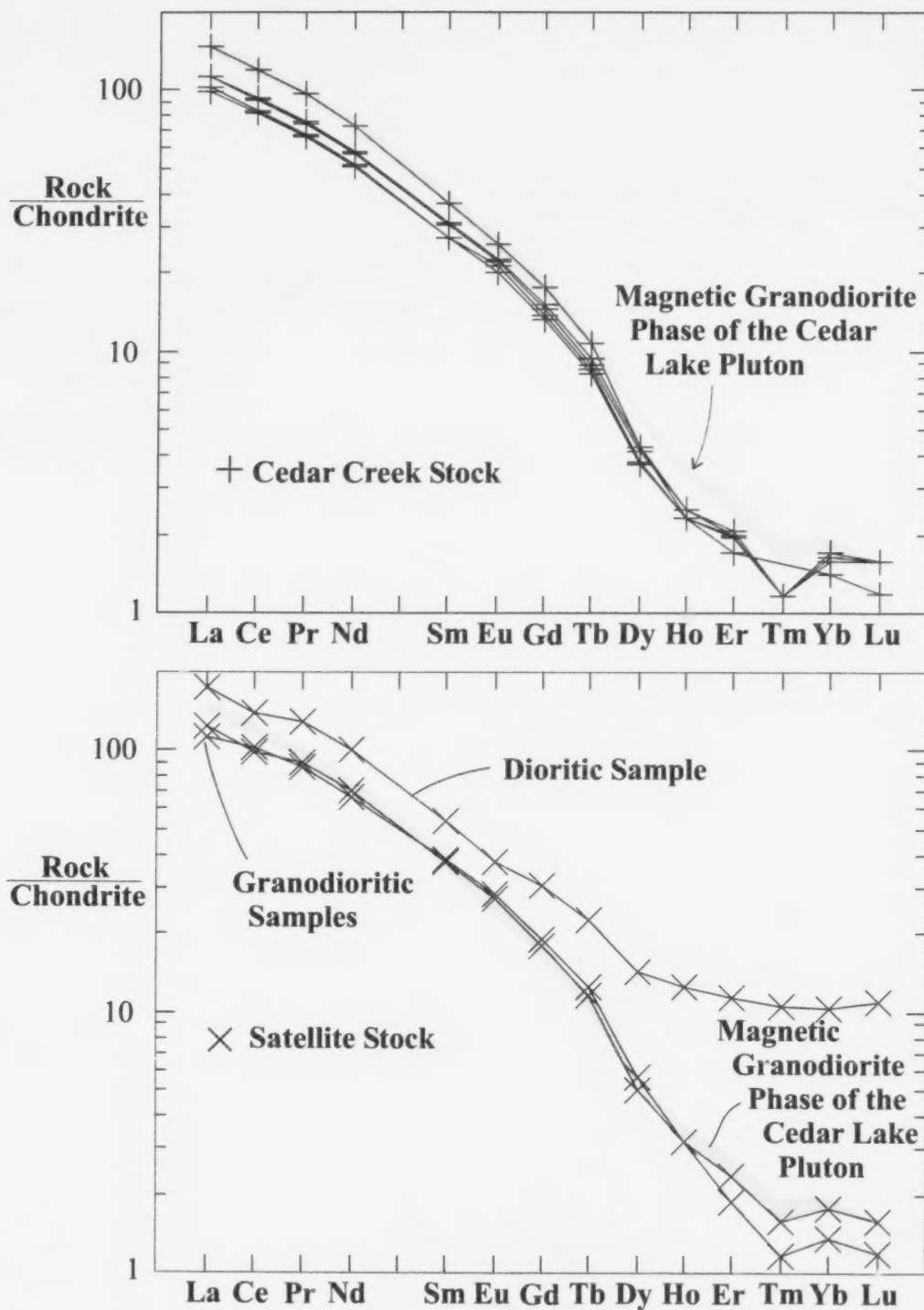


Figure 38. Chondrite normalized REE data for the Cedar Creek stock and Satellite stock with the field (shaded) for the magnetic granodiorite phase of the Cedar Lake pluton for comparison. Data for the Satellite stock includes two granodioritic and one dioritic sample. Chondrite normalization values from Sun and McDonough (1989).

Petrogenetic Interpretation

The mantle-type Nd isotopic signature of a single sample limits the involvement of significantly older crustal material in the petrogenesis of the Cedar Creek and Satellite stocks. A sedimentary crustal source is also improbable due to the absence of inclusions, aluminous mineralogy and strongly peraluminous chemistry that characterizes S-type granites. An intermediate to felsic igneous crustal source is also unlikely. Crustally derived granites tend to be biotitic, moderately peraluminous and characterized by lower Sr and Eu due to retention in residual plagioclase (Beakhouse and McNutt, 1991). The Cedar Creek and Satellite stocks lack these characteristics and this, together with the absence of meta-igneous inclusions, suggests that an intermediate to felsic crustal source is unlikely.

Most of the characteristics of the granodioritic component of the Cedar Creek and Satellite stocks are comparable to those of Archean TTG suite plutons interpreted to be derived by the partial melting of tholeiitic basalt at lower crustal or upper mantle depths. The principal difficulty with this model is, as discussed in detail for the Cedar Lake pluton, the extreme REE fractionation and in particular the high LREE abundance that can only be reconciled with this model if the source basalt had an unusual primary LREE enrichment.

The granodioritic components have low Mg#, Ni and Cr that could only be reconciled with a mantle source (sanukitoid) model if they were highly fractionated members of this suite. The single dioritic sample from the Satellite stock has elevated Mg#, Ni and Cr coupled with high LILE and HFSE abundances and could represent a primary or slightly fractionated sanukitoid magma (cf. Rocky Islet Bay complex and Ottertail Lake pluton samples of Shirey and Hanson, 1984).

The foregoing suggests that the Cedar Creek and Satellite stocks are characterized by a predominant component that is unlikely to have a significant crustal component but its petrogenesis is otherwise poorly constrained. It is most readily reconciled with a TTG model with an unusually LREE enriched basaltic source. The minor monzodioritic component recognized only in the Satellite stock may be a primary sanukitoid (mantle melt) magma. As discussed above for the various components of the Cedar Lake pluton, the Cedar Creek and Satellite stocks may represent a magmatic system that originated as a hybridization of TTG and sanukitoid magmas.

Fourbay Lake Pluton

Examination of the Fourbay Lake pluton is restricted to its southern portion where it has a uniform hornblende-biotite ($\pm$ clinopyroxene) quartz monzodioritic composition (Figures 3 and 4) and medium grained, hypidomorphic granular texture. Plagioclase is subhedral and generally has only weak, patchy alteration to a fine-grained mixture of white mica, epidote and carbonate. One sample investigated in detail (7239) is characterized by relatively uniform plagioclase (An₂₅₋₂₉) with minor rims of more sodic

plagioclase (An_{18}) whereas a second sample (7240) has a uniform, more calcic (An_{34-38}) plagioclase. Microcline ($Or_{94}Ab_6$) is perthitic and is intergranular displaying no tendency to form megacrysts. Quartz is an anhedral phase that is generally intergranular with respect to plagioclase and ferromagnesian minerals but in several samples it is slightly rounded suggesting it has undergone minor resorption.

Mafic mineralogy is complex and is similar to that observed in the Gowan Lake pluton with hornblende greatly predominating over biotite (Figure 4) and minor clinopyroxene cores in hornblende. The only notable difference is that the markedly acicular amphibole seen in some of the Gowan Lake pluton samples are not observed in the Fourbay Lake pluton. Amphibole (edenite) occurs as fresh, euhedral to subhedral crystals that locally are cored by clinopyroxene (diopside) (Figure 39). Biotite commonly overgrows amphibole but biotite plates locally occur within amphibole (Figure 39) suggesting that the crystallization interval of these two phases overlapped. Biotite is locally weakly chloritized and commonly has Fe-Ti oxide plates along cleavage planes (Figure 39).

Fe and Fe-Ti oxides are relatively abundant (~1-2%) and account for the aeromagnetic signature of the pluton. The most abundant variety of oxide is simple magnetite octahedra. Most of the remainder are 2-phase oxide grains that have a magnetite and titanomagnetite component and are commonly rimmed by sphene. Other volumetrically insignificant varieties include discrete ilmenite plates as well as Ti-rich magnetite plates occurring within biotite cleavage planes.

Other primary accessory minerals include sphene, epidote, apatite and zircon. Weak secondary alteration includes saussuritization of plagioclase feldspar and chloritization of biotite.

Geochemical Characteristics

Four samples from the Fourbay Lake pluton suggest a uniform composition that is similar in many respects to the Gowan Lake pluton (Table 3, Figures 23-37 and 40). Noteworthy characteristics include its distinctly metaluminous, mildly alkaline nature and high abundance of both LILE and a wide range of HFSE. The abundance of HREE is comparable to that of the Gowan Lake pluton (8-11X chondrite) and LREE are, on average, more enriched resulting in REE fractionation ranging from moderate to high. ϵ_{Nd} for a single sample is +2.4.

Petrogenetic Interpretation

The Fourbay Lake pluton is interpreted to be genetically related, or to have developed along a parallel petrogenetic path, to the Gowan Lake pluton. Although the Fourbay Lake pluton is more homogeneous and lacks the abundance of mafic enclaves that characterizes the Gowan Lake pluton, the two units have close similarities in terms of their general mineralogy (particularly the distinctive, complex mafic and oxide mineralogy), accessory minerals, magnetic properties and mineral and whole rock

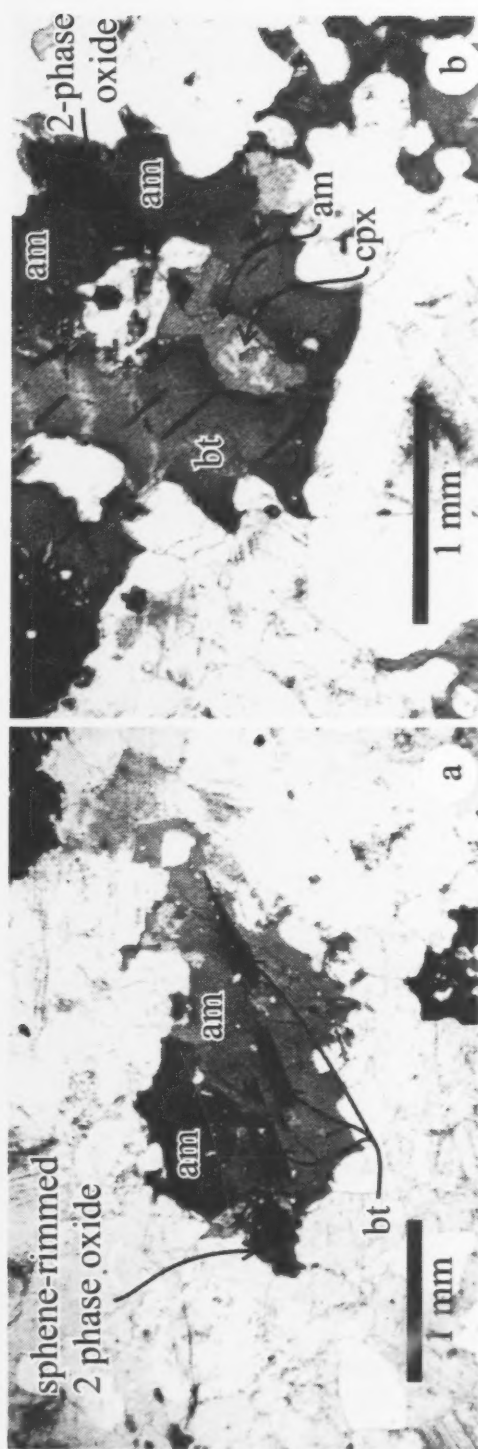
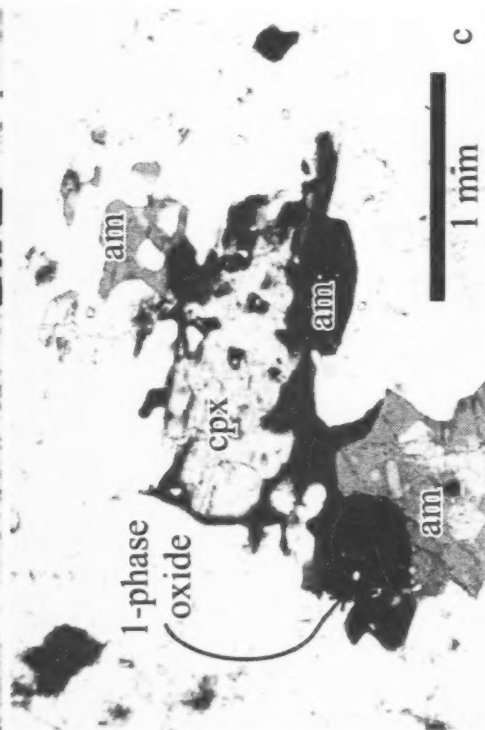


Figure 39. Photomicrographs illustrating the textural relationships between ferromagnesian minerals in the Fourbay Lake pluton.

39a) Biotite included within amphibole with adjacent 2-phase oxide grain rimmed with sphene

39b) Clinopyroxene core in amphibole with both included in large biotite with Fe-Ti oxide plates.

39c) Clinopyroxene core in amphibole adjacent to single phase Fe oxide.



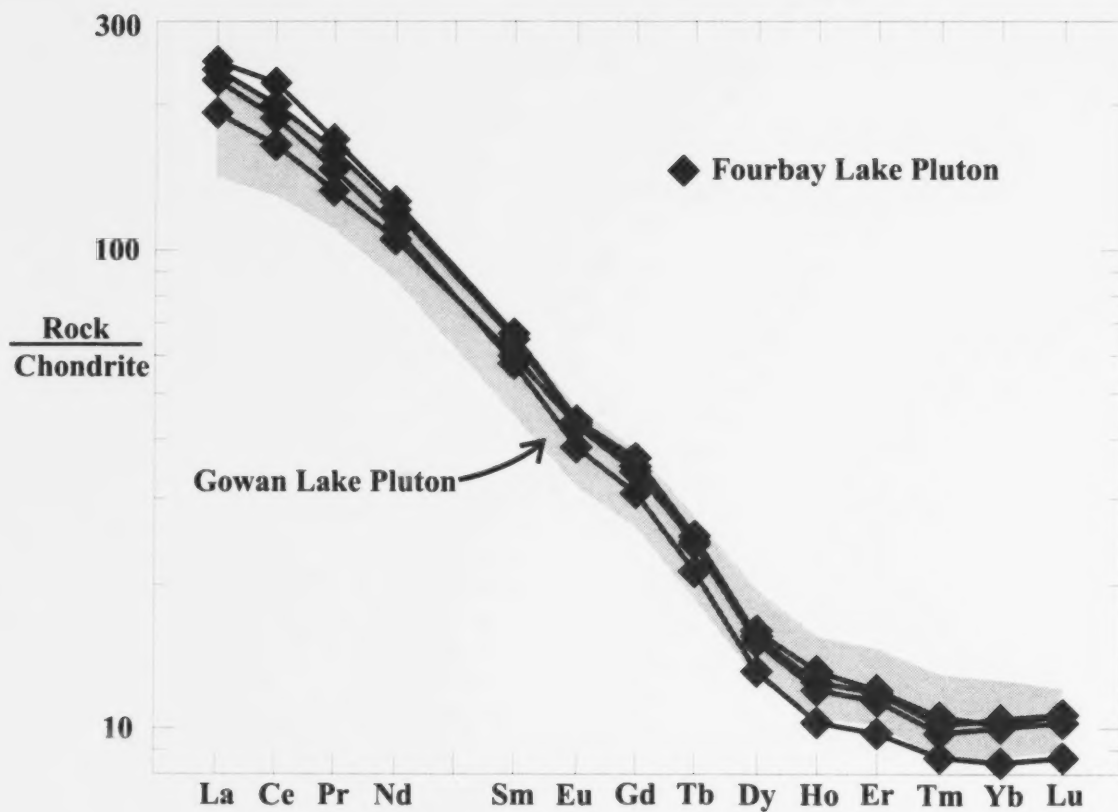


Figure 40. Chondrite normalized REE spectra of the Fourbay Lake pluton compared to that of the Gowan Lake pluton. Chondrite normalization values are from Sun and McDonough (1989).

geochemical characteristics. They also have similar isotopic signatures and U-Pb ages of 2678 ± 2 Ma for the Gowan Lake pluton (Corfu and Muir, 1989a) and 2677.7 ± 1.1 Ma for the Fourbay Lake pluton (Davis et al., 1998).

Like the Gowan Lake pluton, the involvement of significantly older continental crust in the petrogenesis of the Fourbay Lake pluton is limited by the mantle-type Nd isotopic characteristic. Involvement of a slightly older intermediate to felsic igneous or sedimentary sources is further limited by the relatively melanocratic, strongly metaluminous character of the pluton as well as the abundance of Sr and Eu which would be expected to be depleted by residual plagioclase in the source.

A mafic crustal (TTG model) source is also unlikely in view of the mildly alkaline, high-K calc-alkalic nature of this pluton that contrasts with the characteristics of plutons successfully modeled as having such a source. The extremely high LREE and LILE abundances are also difficult to reconcile with this model as the source would be required to have an unusual composition. The relatively mafic, SiO_2 -poor nature of these rocks would require relatively high degrees of melting which would pose a further difficulty in explaining the high LREE and LILE abundances.

A sanukitoid (metasomatized mantle melt) model is most easily reconciled with the characteristics of the Fourbay Lake pluton and its interpreted association with the Gowan Lake pluton for which such an interpretation is favored. The relatively low Mg# and Ni and Cr abundances characterizing the Fourbay Lake pluton indicate that it is not a primary sanukitoid melt and must be a relatively highly fractionated member of the sanukitoid suite. The relatively homogeneous, enclave-poor nature of the pluton compared to the Gowan Lake pluton is consistent with the interpretation that it may have undergone more fractionation.

Musher Lake Pluton

The Musher Lake pluton is a moderately mafic granodiorite to tonalite with subequal abundances of biotite and hornblende (Figures 3 and 4). All samples display a hypidiomorphic granular texture with plagioclase exhibiting a tendency to be slightly coarser grained imparting a weakly porphyritic character.

Plagioclase is subhedral to euhedral and many, though not all, crystals display prominent normal zoning from relatively calcic cores (labradorite) to more sodic rims (oligoclase-andesine). This zoning is also commonly reflected in the distribution of moderately strong alteration (white mica, epidote and carbonate) that tends to be concentrated in specific zones. Detailed investigation of a single sample confirms that there is a considerable range in plagioclase composition within a single sample with one crystal being relatively uniform (An_{29-31}) and others exhibiting a range of compositions with moderately strong normal zoning (e.g., An_{51} to An_{33} and An_{43} to An_{33}). Microcline is intergranular with respect to the other major rock forming minerals and is interpreted to be a late crystallizing phase. In several thin sections, this intergranular microcline

displays optical continuity over cross-sectional areas of several square centimeters, reflecting incipient megacryst formation that was not evident in the field.

Amphibole (edenite) and biotite generally form discrete subhedral crystals although locally biotite appears to be both included in and overgrowing amphibole. This is interpreted to indicate that both are primary magmatic phases with overlapping crystallization intervals. Amphibole is generally fresh whereas biotite exhibits a range, being fresh or very weakly chloritized in some samples (7075 and 7813) and moderately (sample 7093) to intensely (samples 7207 and 7261) chloritized in others. Biotite in one sample (7093) includes grains similar to the interpreted magmatic biotite as well those with included fibrous aggregates in addition to the abundant sphene and epidote inclusions seen in the magmatic biotite. Detailed investigation of these fibrous aggregates indicates that they are composed of finely intergrown orthoamphibole (Mg-rich gedrite) and epidote (Figure 41). Gedrite is unknown as a primary magmatic mineral and is interpreted to have a metamorphic or metasomatic origin (Deer et al., 1966). There is no evidence, other than these clots, that the pluton has been metamorphosed or significantly altered. Consequently, the general form and mineralogy of these clots suggest that they are not magmatic phases and likely reflect incorporation of metamorphic or alteration assemblages from the host metasedimentary country rocks.

Epidote crystals up to 1 mm long commonly have an euhedral form and locally having simple twinning. This, together with their inclusion within relatively early crystallizing phases (e.g., amphibole), suggests that it is an early magmatic phase. Minor oxide, occurring both as octahedra and in association with sphene, is generally composed of predominant magnetite together with a subordinate Ti-bearing magnetite. Sphene is relatively abundant (>1% in some samples) as an early euhedral crystal. Other primary accessory minerals include apatite and zircon.

Plagioclase feldspar and biotite exhibit various degrees of alteration to white mica-epidote-carbonate and chlorite, respectively. Secondary sulphides were noted in several samples.

Geochemical Characteristics

The Musher Lake pluton has high-K calc-alkaline affinity with relatively high abundances of alkali elements but still lying within the sub-alkaline field. It is mildly metaluminous with intermediate SiO₂ abundance and Mg# (Table 3). The composition is intermediate, in most respects, between that of the Cedar Lake pluton and Gowan Lake pluton (Figures 23-37). The geochemical characteristics of the Musher Lake pluton are most closely comparable to those of the high-Mg granodiorite of the Heron Bay pluton and pyroxene granodiorite of the Cedar Lake pluton, although even for these cases there are significant differences. REE patterns are moderately fractionated with 4-6X chondrite HREE and negligible Eu anomalies (Figure 42). $\epsilon_{\text{Nd}}^{2679\text{Ma}}$ (+2.3) for sample 7075 is comparable to estimates of Late Archean depleted mantle.

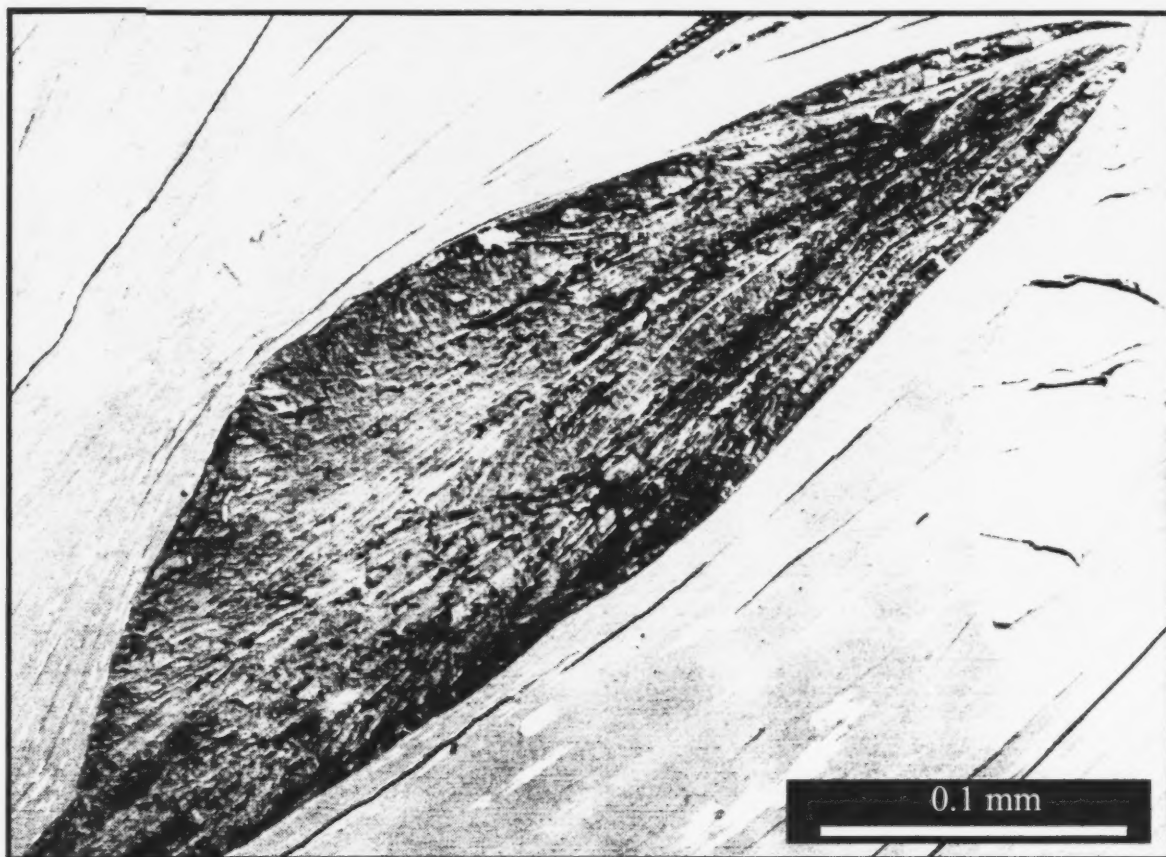


Figure 41. Electron backscatter image of clot consisting of fibrous intergrowth of epidote and gedrite (Sample 7093, Musher Lake pluton)..

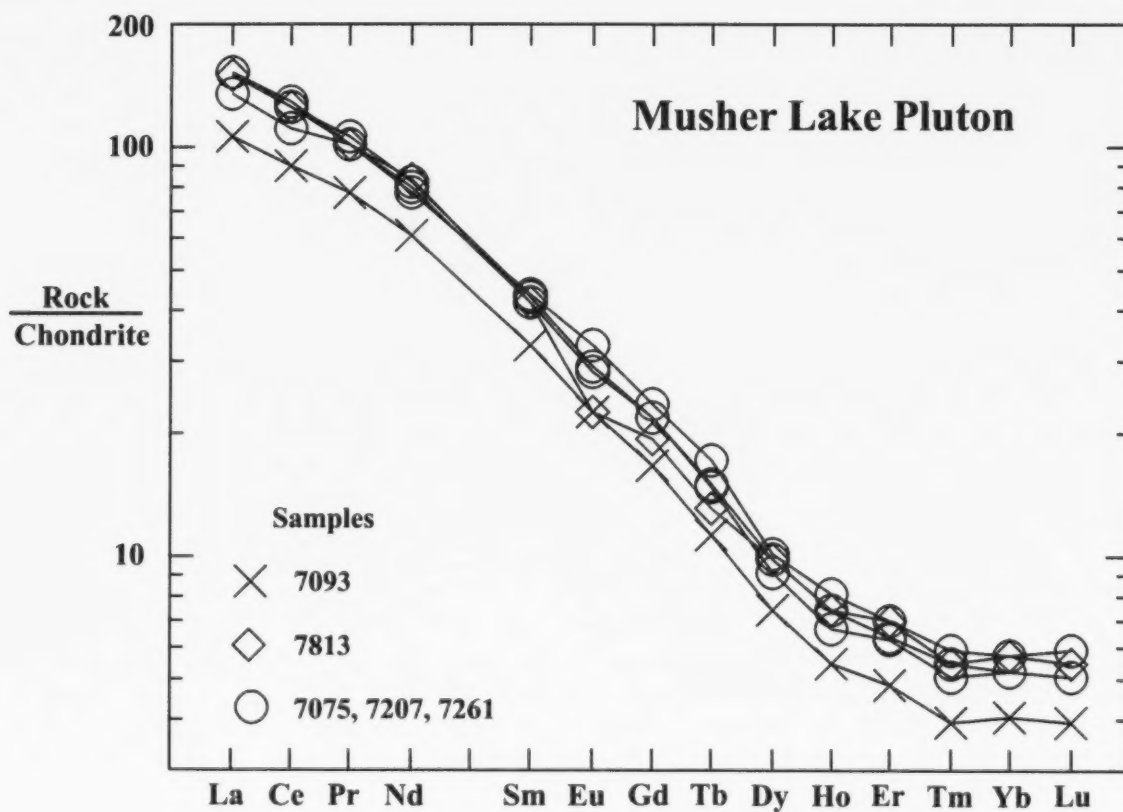


Figure 42. Chondrite normalized REE spectra for the Musher Lake pluton. Chondrite normalization values are from Sun and McDonough (1989).

These general similarities notwithstanding, there are noteworthy geochemical differences between the individual samples that may indicate that a different range of processes have influenced the composition of different samples. The poorly exposed nature of this pluton also makes it conceivable that more than one phase/pluton may be represented within these samples. Sample 7093, compared to the other samples, has less CaO, Rb, Ba and REE lacks the metaluminous character of the other samples. The latter characteristic, together with the anomalous biotite occurring in this sample, may indicate some interaction with metasedimentary country rocks. Samples 7261 and 7813 have notably higher K₂O and Rb compared to other samples although they show no indication of being more highly fractionated in terms of other variables (e.g., they are similar with respect to SiO₂, MgO and Mg#). Sample 7813 also has a more strongly negative Eu anomaly than the other samples suggesting possible plagioclase fractionation although expected, concomitant Sr depletion is not evident. The lack of any systematic covariation as would be expected for simple crystal-liquid fractionation is interpreted to indicate that the variability may reflect source variability or differential contamination.

Petrogenetic Interpretation

The poor exposure and possibility that all samples assigned to the Musher Lake pluton may not share a common history complicates interpretation of the petrogenesis of this pluton. The single sample for which isotopic data is available has mantle-type isotopic characteristics that limit the involvement of significantly older continental crust although sample 7093 may have interacted with altered felsic metavolcanic or pelitic metasedimentary rocks. The high Sr and lack of appreciable Eu anomalies (except for sample 7813), together with the relatively mafic, magnesian character of the pluton suggest that a significant crustal melt component is unlikely.

The geochemical characteristics of sample 7093 has some similarities to those of Archean and younger high-Al, TTG magmas interpreted to originate by partial melting of tholeiitic basalt and lower crustal or upper mantle depths (e.g., Drummond and Defant, 1990). The REE pattern for sample 7093 (Figure 42) is, for example, only slightly elevated compared to those of type 2 tonalites from the belt bounding batholiths that as discussed above may be derived by melting of basalt with somewhat enriched and fractionated REE. The more primitive character (e.g., lower SiO₂ and higher MgO and TiO₂) of the of sample 7093 would, however, require a higher degree of melting which would make it more difficult to reconcile with the observed moderately elevated REE and LILE abundances. The other samples are even more difficult to reconcile with this model for the same reasons. Consequently, the TTG model does not appear, on its own, to provide an adequate explanation for the petrogenesis of the Musher Lake pluton.

The Musher Lake pluton does not have characteristics indicative of a primary sanukitoid magma (Shirey and Hanson, 1984) but could be a fractionated member of the sanukitoid suite. Mg# and Ni and Cr abundances are significantly lower than primary sanukitoid magmas but are elevated relative to magmas of possible TTG affinity discussed above. In spite of their relatively primitive character as indicated by Mg# and SiO₂, TiO₂, Ni and Cr abundances, these samples have moderately high abundances of REE and LILE. This

primitive/evolved duality is a characteristic of sanukitoid magmas. Although a sanukitoid petrogenetic model for the Musher Lake pluton cannot be clearly demonstrated in the absence of related primary sanukitoid magmas, it is interpreted to be the most likely explanation.

Melgund Stock

The Melgund stock has a uniform quartz dioritic composition with a comparatively high color index (21 – 27) dominated by hornblende (Figures 3 and 4). Texture is uniformly medium grained and weakly plagioclase porphyritic.

Plagioclase is subhedral to euhedral, up to 8 mm long and displays prominent oscillatory zoning that exerts a strong control on the distribution of moderate to intensely developed alteration. The alteration (white mica, epidote and carbonate), though fine grained, is somewhat coarser than typically occurs in other plutons in the Hemlo greenstone belt area. Detailed investigation of one sample revealed oscillatory zoning in the range An_{40-53} with narrow, less altered, rims of more sodic (An_{15-18}) plagioclase. Microcline is intergranular with respect to all other major mineral phases. It is only very weakly microperthitic and has a uniform, nearly pure (Or_{97}) composition in one sample.

Amphibole is fresh and subhedral. Detailed investigation of one sample reveals it to be a relatively magnesian amphibole ranging from magnesiohornblende to actinolite (average is magnesiohornblende; $Mg/Mg+Fe \sim 0.66$ and $Si \sim 7.42$). Biotite is moderately to strongly chloritized.

Sphene and epidote and, to a lesser extent, apatite are relatively abundant accessory minerals. Other primary minerals present in trace amounts include zircon and possibly sulphide and oxide. With the exception of very minor 2-phase (magnetite and Ti-bearing magnetite) oxides associated with sphene and thin plates within biotite, oxides (magnetite) are invariably closely associated with sulphides (primarily pyrite with rare chalcopyrite). Textural relations were not clear with reference to whether or not these sulphide-oxide grains are primary or secondary.

Geochemical Characteristics

Based on a limited number of samples, the Melgund stock appears to have very little internal compositional variation. These rocks are distinctly metaluminous with relatively low SiO_2 , high Mg# and high abundances of Ni, Cr, V and Co. Unlike other relatively quartz-poor, mafic units (Gowan Lake pluton, Fourbay Lake pluton), these rocks have comparatively low abundances of P, Zr, Nb and Th (Figures 23-37). Comparatively low LILE also sets the Melgund stock apart from these other plutons as does low LREE ($Ce_N \sim 50X$ chondrite) and resulting weakly fractionated REE patterns (Figure 43). ϵ_{Nd} derived from an estimated age of 2685 Ma is +2.3.

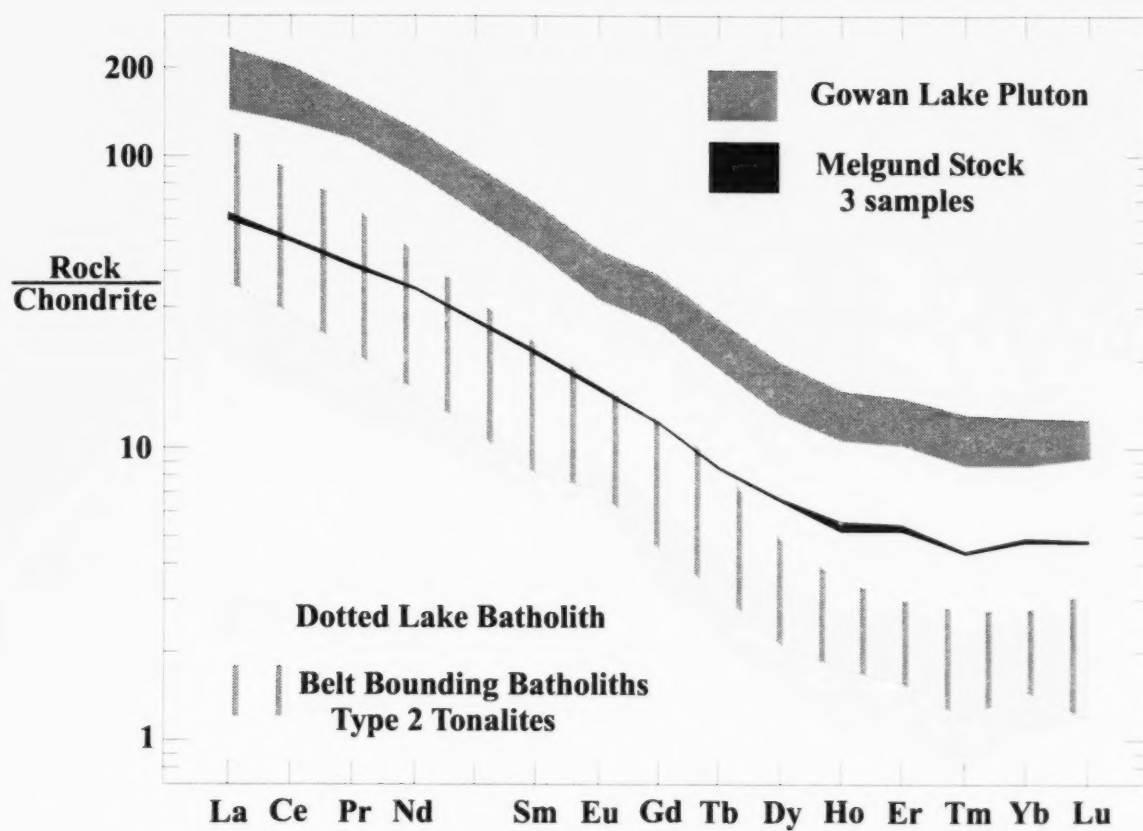


Figure 43. Chondrite normalized REE spectra for the Melgund stock compared to the ranges for an interpreted sanukitoid suite pluton (Gowan Lake pluton) and interpreted TTG suite units (Dotted Lake batholith and type 2 tonalites from the belt bounding batholiths). Chondrite normalization values are from Sun and McDonough (1989).

The Melgund stock is geochemically unique among granitoid rocks associated with the Hemlo greenstone belt. The most similar samples are the higher SiO₂ samples among the dioritic phases associated with the Cedar Lake pluton although even in comparison to these rocks, the Melgund stock has significantly lower P₂O₅, Y and Zr. REE are similarly fractionated but are much less abundant in the Melgund stock.

Petrogenetic Interpretation

The distinctly metaluminous character, high Mg# and Ni and Cr abundances, low LILE abundances and mantle-type Nd isotopic signature are all inconsistent with significant involvement of older intermediate to felsic igneous or metasedimentary rocks in the petrogenesis of the Melgund pluton.

Several aspects of the geochemistry of the Melgund stock are consistent with a TTG (partial melting of tholeiitic basalt) model. The low LILE abundances and moderately fractionated REE pattern with relatively depleted HREE and negligible Eu anomalies are similar to those of the Dotted Lake batholith and type 2 tonalites of the belt bounding batholiths, both of which are interpreted to have a TTG signature. However, the high abundances of MgO, Ni and Cr and highly magnesian nature of the whole rock and amphibole are difficult to reconcile with such a model unless the source basalt was unusually primitive and underwent relatively high degrees of melting.

The magnesian nature of the whole rock and amphibole composition together with the high MgO, Ni and Cr abundances in the whole rocks suggest a possible sanukitoid (mantle melt) origin for the Melgund stock. The LILE, HFSE and REE abundances are low in comparison to other units inferred to have such an origin in the Hemlo greenstone belt area (e.g., Gowan Lake and Fourbay Lake plutons) and within the low end of the range for interpreted sanukitoid suite plutons from elsewhere in the Superior province (Shirey and Hanson, 1984; Stern et al., 1988; Sutcliffe et al., 1990; Stern and Hanson, 1991). These differences would require that the mantle source region for mantle-derived melts be heterogeneously metasomatized to give rise to the range of observed characteristics of inferred sanukitoid suite magmas.

Neither the TTG nor the sanukitoid model can be unambiguously demonstrated or refuted for the Melgund stock but the latter model is interpreted to be the most reasonable explanation.

Picture Island Pluton

The Picture Island pluton is a relatively uniform biotite granodiorite to granite (Figures 3 and 4). The relatively low color index and absence of hornblende sets this pluton apart from most of the other later plutonic group units. The only other units having these general mineralogical attributes are the Dotted Lake batholith and the Ogilvie Island pluton (Figure 1). The pluton has a relatively uniform hypidiomorphic granular texture and is relatively coarse-grained (5-8 mm).

Plagioclase is subhedral and has moderate to strong patchy alteration to white mica, epidote and carbonate. Plagioclase displays some oscillatory zoning in the range An₄₃₋₁₉ but is mostly relatively uniform (~An₃₁). Microcline (Or₉₅) is intergranular with respect to the main rock forming minerals. Quartz grains tend to be rounded and contain numerous, optically discontinuous sub-domains.

Biotite occurs as discrete, subhedral grains and in polycrystalline clots along with epidote and sphene. In some cases, numerous smaller biotite grains occur along the edge of larger biotite crystals. Biotite is moderately to intensely chloritized. Epidote occurs both as a fine-grained alteration product of plagioclase and as larger, subhedral to euhedral, rarely twinned, primary magmatic crystals. Other primary accessory minerals include sphene, opaque oxides, apatite and zircon. Minor secondary sulphide and carbonate is also commonly present.

Geochemical Characteristics

The leucocratic, biotitic nature of the Picture Island pluton is reflected in its comparatively siliceous, mildly peraluminous character (Table 3). Low Mg# and CaO also indicate the comparatively geochemically evolved nature of this unit. Other distinctive characteristics include relatively low Na₂O, Al₂O₃, Ba and Sr and high U, Th, Ce, Yb and Ta (Figures 23-37). REE are moderately highly fractionated with weak negative Eu anomalies (Figure 44). ϵ_{Nd} based on an estimated age of 2688 Ma is +2.3.

In terms of most indices of differentiation (e.g., SiO₂, TiO₂, CaO, Mg#), the Picture Island stock overlaps with a number of major (Type 1 and 2 belt bounding batholith, most evolved samples of Heron Bay pluton and least evolved samples of Dotted Lake batholith) and minor (Botham stock and Cedar Creek stock) units associated with the Hemlo greenstone belt. In spite of these general major element geochemical similarities, the Picture Island stock is quite distinctive in terms of trace element characteristics, notably relatively high abundances of Nb, Th, Ta, Y and Yb. Other distinctive features that set this pluton apart from some of these units include relatively lower Sr abundance, more prominent negative Eu anomalies and mildly peraluminous character. These differences indicate that the Picture Island stock does not have any close geochemical analogues and is unique in the Hemlo greenstone belt area.

Petrogenetic Interpretation

The Picture Island pluton is unique in the Hemlo greenstone belt area in terms of both its textural/mineralogical and geochemical characteristics. The mantle-type Nd isotopic signature of the Picture Island stock is inconsistent with petrogenetic models that involve significant recycling of much older fractionated (sedimentary or intermediate to felsic igneous) crust. The weakly peraluminous nature of the Picture Island stock contrasts with the strongly peraluminous nature of most Superior province S-type granitoids (e.g., Ghost Lake batholith (Breaks, 1989)). Most of the mineralogical and geochemical characteristics, notably the weak negative Eu anomalies and relatively low Sr abundance,

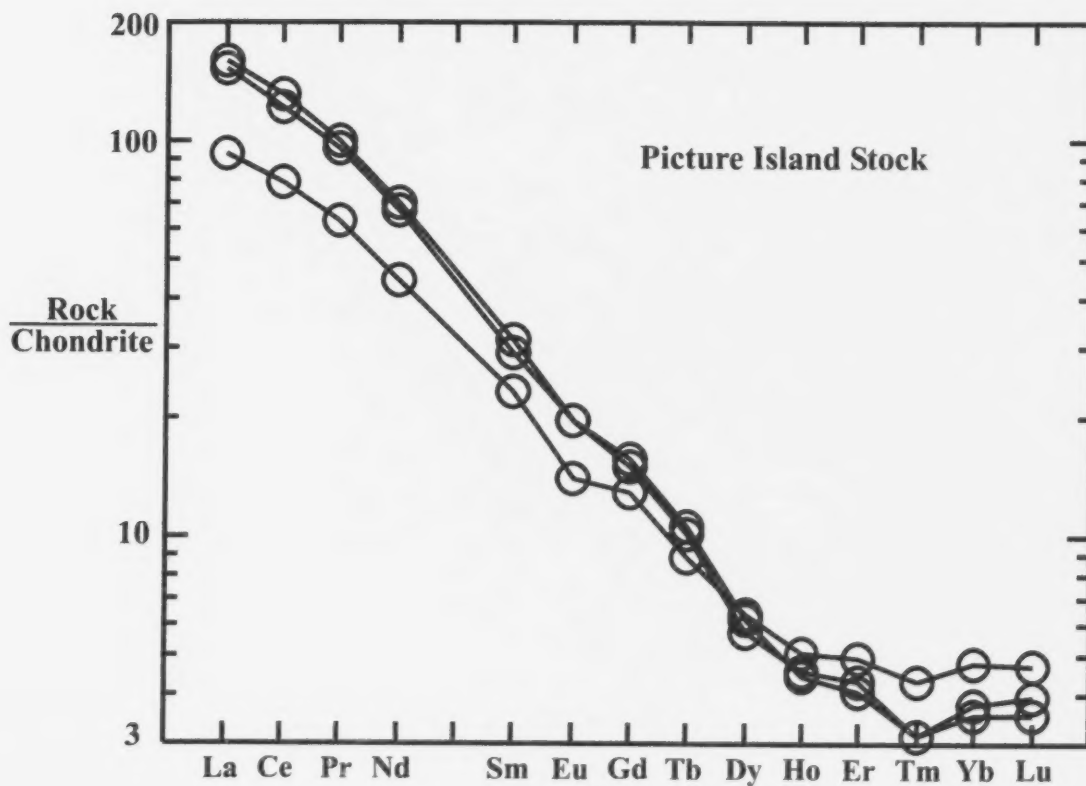


Figure 44. Chondrite normalized REE spectra for the Picture Island stock. Chondrite normalization values are from Sun and McDonough (1989).

are consistent with partial melting of slightly older TTG type tonalitic rocks (e.g., Beakhouse and McNutt, 1991).

The Picture Island pluton shares many characteristics with the TTG suite, however it also differs in certain respects. Relative to TTG suite plutons in the Hemlo greenstone belt area, the Picture Island stock has more abundant K_2O , Th, Y and REE and lower Na_2O . These contrasts are also evident with respect to TTG magmas more generally (Drummond and Defant, 1990). The observed weakly negative Eu anomalies are also unusual for TTG magmas, although the magnitude of the negative Eu anomaly correlates inversely with CaO and Sr abundance, suggesting it is possible that this difference may reflect fractional crystallization of plagioclase. Consequently, the TTG model (partial melting of mafic crust) cannot be discounted, although it is not readily reconciled with some of the data.

The peraluminous composition and biotite-dominated mafic mineralogy, together with low Mg# and low abundance of MgO, Ni and Cr, all suggest that a sanukitoid (direct mantle melting) is an unlikely origin for the Picture Island stock.

A conclusive petrogenetic model for the Picture Island stock is not forthcoming from this study. Partial melting of young TTG-type crust, such as is represented by the types 1 and 2 tonalitic rocks of the belt bounding batholiths, is consistent with most observations and is the preferred model. Partial melting of tholeiitic basaltic crust at lower crustal or upper mantle depths is also a plausible model but would require that the pluton be a product of low degree of melting of unusually fractionated (LILE-enriched, LREE enriched) basaltic crust and that plagioclase fractionation occurred during or subsequent to the melting event.

Ogilvie Island Pluton

The Ogilvie Island pluton is exposed on a small island in Lake Superior and the extent of the unit is unknown. Two samples selected from Ogilvie Island are similar in terms of their mineralogical and geochemical characteristics.

Both samples are biotite tonalites with one of the samples containing a small amount of hornblende. Much of the plagioclase is relatively compositionally uniform (An_{21} to An_{27}) although the rims of many grains as well as many discrete smaller grains are distinctly more sodic (An_4 to An_{14}). Plagioclase is moderately to strongly altered to a fine grained mixture of white mica, epidote and carbonate. The alteration is commonly zone controlled with the less sodic plagioclase being generally more intensely altered. Microcline (Or_{95}) occurs as small, intergranular, fresh grains. Quartz has patchy to undulose extinction and is intergranular with respect to plagioclase and ferromagnesian minerals.

Biotite is the predominant ferromagnesian mineral. It occurs both as relatively large, optically continuous platy crystals and polycrystalline aggregates consisting of abundant, small biotite crystals. In the later type, the biotite grains may be either randomly oriented

or have a general preferred orientation subparallel to the long dimension of the aggregate grain. The polycrystalline biotite aggregates may reflect conversion of original amphibole to biotite either during crystallization (e.g., Speer, 1987) or during a subsequent hydrothermal alteration event (e.g., Brimhall et al., 1985) although no textures indicative of such a reaction are observed in the sample containing a minor amount of amphibole. Both biotite and amphibole (magnesiohornblende to actinolite) are unusually magnesian compared to that found in most other plutons in the Hemlo greenstone belt area.

Epidote is abundant and occurs in a variety of forms. Most abundant are subhedral to euhedral crystals that commonly display simple twinning and are interpreted to be primary magmatic minerals. Several large, anhedral grains are characterized by vermicular quartz intergrowths. Fine grained, granular epidote is a minor, widely distributed alteration product of plagioclase. Other primary magmatic accessory minerals include sphene, apatite and zircon. Secondary minerals, in addition to the alteration products of plagioclase discussed above, include chlorite (after biotite) and carbonate. The latter occurs both as fine grains within biotite and relatively coarse intergranular grains that may reflect post-crystallization alteration.

Geochemical Characteristics

The Ogilvie Island pluton is unique among plutons with biotite-dominated mafic mineralogy associated with the Hemlo greenstone belt in being mildly metaluminous (ACNK ~ 0.96) and having a high Mg# (56). This may be consistent with the hypothesis that some of the biotite may be a late magmatic or hydrothermal alteration product of amphibole. Relatively high abundances of Ni (43 ppm) and Cr (66 ppm) are also distinctive with respect to biotitic plutons (Figures 34 and 35) and more closely comparable to abundances characterizing the more mafic, hornblende-dominated plutons of possible sanukitoid affinity (Gowan Lake pluton, Fourbay Lake pluton, Melgund stock). REE are moderately fractionated ($Ce_N/Yb_N \sim 21$) with flat HREE (~3X chondrite) and weak positive Eu anomalies (Figure 45). These characteristics, together with low to moderate abundance of LILE and HFSE, are more typical of TTG suite plutons than sanukitoid suite plutons. The Melgund stock, though less geochemically evolved, is perhaps the closest analogue to the Ogilvie Island pluton in terms of its geochemical characteristics.

Petrogenetic Interpretation

The limited amount of data available for the Ogilvie Island pluton makes it difficult to unambiguously assign a petrogenetic origin. The metaluminous nature, high Mg#, abundant Ni and Cr, relatively low LILE abundance and presence of weakly positive Eu anomalies are all difficult to reconcile with either crustal melting or significant crustal contamination. The relatively low LILE and HFSE abundances and REE patterns are similar to those characterizing TTG suite plutons. However, as for the Melgund stock, high Mg# and Ni and Cr abundances would require exceptionally primitive source basalts or very high degrees of melting that would be unlikely to give rise to the other general

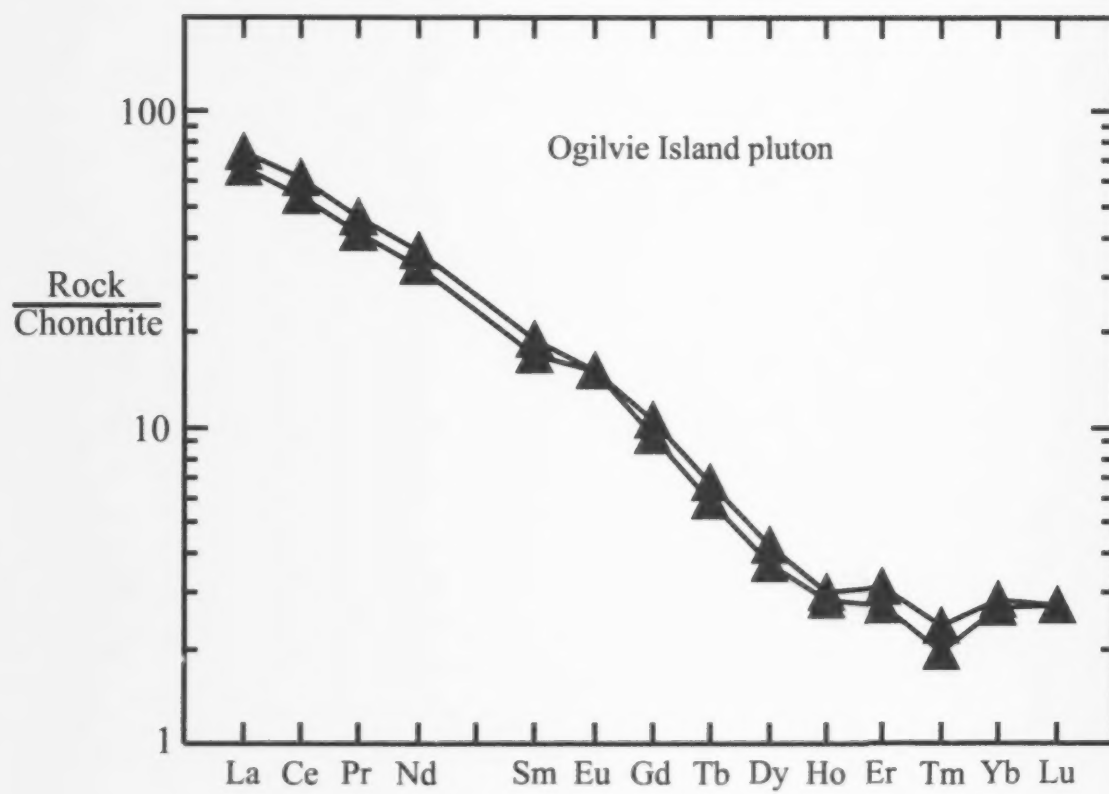


Figure 45. Chondrite normalized REE spectra for the Ogilvie Island pluton. Chondrite normalization values from Sun and McDonough (1989).

geochemical characteristics of this unit. The high Mg# and Ni and Cr abundances suggest an ultramafic source (sanukitoid model) but the relatively leucocratic, biotite-dominated mineralogy is atypical of rocks inferred to have such an origin.

Botham Stock

The Botham stock consists of two distinctive units. These have been described (Muir, 1997) as a moderately to well foliated, plagioclase-porphyritic, biotite granodiorite and a moderately to weakly foliated, plagioclase-porphyritic granodiorite. The granodioritic composition of the moderately to well-foliated unit could not be confirmed as part of this study as each of the two samples examined consisted of coarse plagioclase phenocrysts in a very fine-grained, quartzofeldspathic matrix in which mineral proportions could not be reliably determined. Moderately intense alteration further complicates estimates of the primary composition of the unit. Muir (1997) noted the presence of hematization and its spatial association with an east-southeast striking fault. Samples examined as part of this study are also characterized by this hematization as well as pervasive chloritization and less uniformly distributed but commonly intensely developed epidote veining. One sample contained randomly oriented muscovite porphyroblasts. Consequently, the primary mineralogy is uncertain and this unit is referred to subsequently as feldspar porphyry.

Examination of the second phase referred to above confirmed its less well-foliated character as well as its granodioritic composition. Plagioclase phenocrysts range from being distinctly to subtly larger than the medium-grained (1-2 mm) matrix. Alteration is much less intense than that characterizing the feldspar porphyry and consists of minor chloritization of biotite, saussuritization of plagioclase and very minor intergranular carbonate. The unit can be characterized as a medium-grained, plagioclase porphyritic, biotite granodiorite. Plagioclase is relatively, uniformly sodic (An_{18} to An_{22}) with little tendency to significant zoning. Microcline ($\sim Or_{96}$) is intergranular with respect to the other major rock forming minerals and exhibits only a very weak tendency to megacryst formation. Quartz displays patchy to undulose extinction and is intergranular with respect to plagioclase and biotite. Biotite is relatively magnesium-rich ($Mg/Fe^{biot} = 0.63$) considering the relatively evolved whole rock composition (e.g., $SiO_2 = 69.4\%$, $Mg\# = 41$) as well as in comparison with that occurring in other plutons including those with an overall more magnesian whole rock composition (Figure 46). Simple, single-phase magnetite octahedra are relatively abundant and are commonly closely associated with epidote. Epidote occurs primarily as large, subhedral crystals that rarely display simple twinning. Other primary magmatic mineral phases include sphene, apatite and zircon.

In contrast to the fine grained, feldspar porphyry phase, the medium grained phase of the Botham stock is characterized by weak development of secondary alteration. Epidote veining and hematitic alteration is not present in this unit and chloritization is only weakly developed in biotite. Other alteration mineralogy includes generally weakly developed alteration of plagioclase to a fine-grained mixture of white mica, epidote and carbonate and minor amounts of larger, intergranular carbonate.

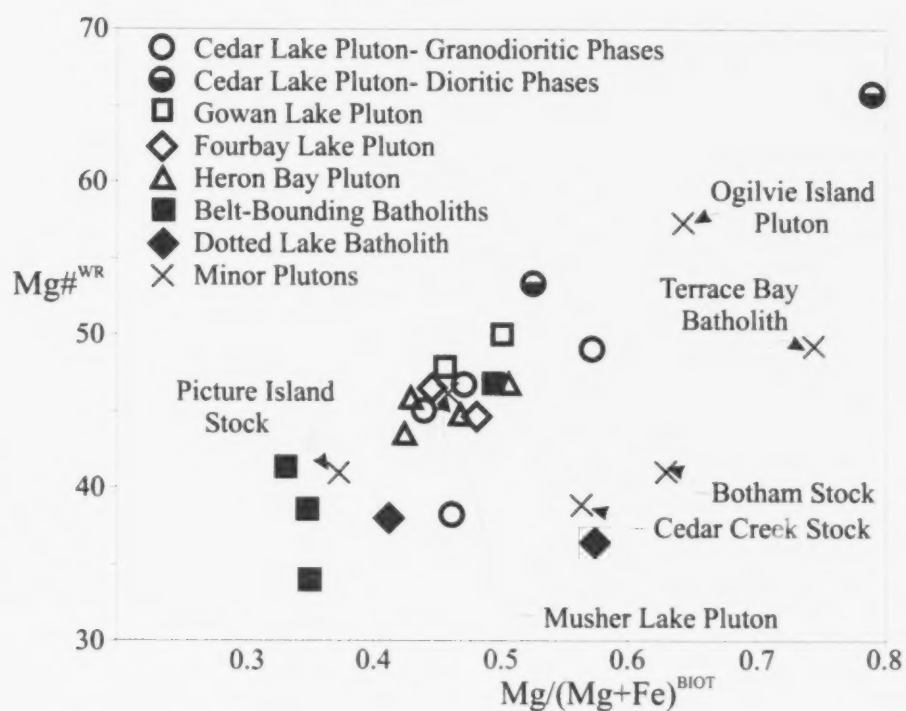


Figure 46. Plot of $Mg\#$ of whole rock versus $Mg/(Mg+Fe)$ for corresponding biotite.

Geochemical Characteristics

The two units that comprise the Botham stock are also geochemically distinct. The medium grained phase is similar to the Picture Island stock with the exception of having much higher Sr (~1200 ppm vs 400 ppm), somewhat higher Na₂O and lower Nb, Th, Ta, Y and Yb. The porphyritic phase is distinguished from the medium grained phase by lower SiO₂, K₂O (~0.6% vs 2.3%), Rb (~20 ppm vs 67 ppm) and higher abundances of a wide range of HFSE as well as higher Mg# (55 vs 42). Both units exhibit highly fractionated REE patterns but REE are anomalously abundant (Ce_N ~ 200-400X chondrite) in the porphyritic phases (Figure 47). A single sample of the medium grained phase of the Botham stock has mantle-type $\epsilon_{\text{Nd}}^{2689\text{Ma}}$ (+2.3).

Petrogenetic Interpretation

The feldspar- porphyry and medium-grained phases that have been grouped within the Botham stock have contrasting field relationships, mineralogy, geochemical characteristics and secondary alteration. This suggests that the two units are genetically and temporally distinct and that this grouping is not warranted.

During the course of this investigation and a previous detailed investigation (T.L. Muir, personal communication, 1999), no intrusive relationships were observed between the feldspar porphyry phase and adjacent metavolcanic/metasedimentary rocks. This unit appears to have experienced at least some of the deformation and alteration superimposed on the supracrustal rocks of the Hemlo area, and consequently the possibility that the feldspar porphyry phase is closely related to the supracrustal rocks cannot be ruled out. The only units analyzed in the Hemlo deposit area that share the distinctive fractionated and REE-enriched geochemical characteristics (T.L. Muir, unpublished data) of the Botham feldspar porphyry phase are aphyric intermediate dikes (Unit 13a of Muir, 1997). This, together with the massive character and general textural similarities to some of the dike phases, suggests that this unit is most reasonably grouped with the myriad of texturally and compositionally diverse dike phases that are abundant in the Hemlo deposit area.

The medium grained granodiorite phase exhibits some similarities to other plutons in the vicinity of the Hemlo greenstone belt but does not closely match the characteristics of any of the major plutons. Among major plutons, it most closely resembles the Dotted Lake batholith in terms of its biotite-dominated mafic mineralogy. Aspects of the geochemistry of these units are also comparable in some respects except that the Botham stock is characterized by greater abundance of Sr, Th and U and more strongly fractionated REE compared to the Dotted Lake pluton. The geochemistry of the medium grained phase of the Botham stock is very similar, notably in its distinctive sodic character, to the Cedar Creek stock, although the latter contains hornblende in addition to biotite. These two units also share the characteristic of having anomalously magnesian biotite considering their relatively evolved nature. The Picture Island stock is

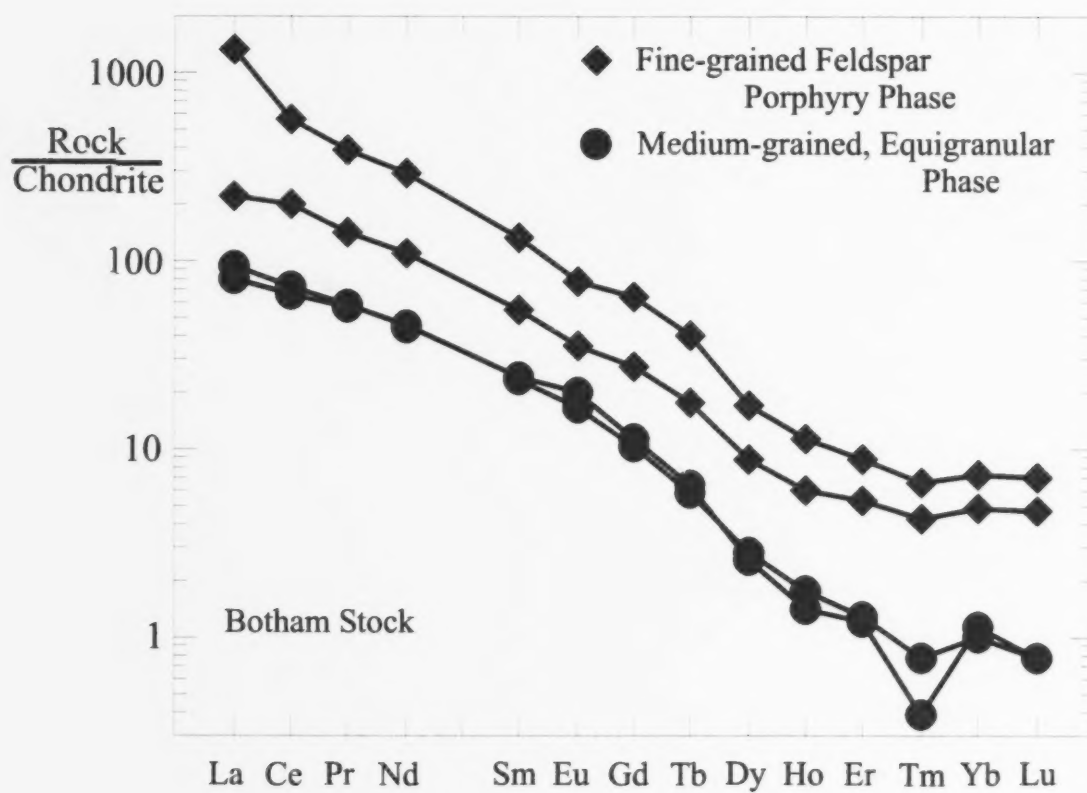


Figure 47. Chondrite normalized REE spectra for the fine-grained, feldspar porphyritic and medium-grained equigranular phases of the Botham stock. Chondrite normalization values from Sun and McDonough (1989).

mineralogically similar to the Botham stock but the former is much less sodic, has lower abundances of a wide range of HFSE and has more abundant and less fractionated REE.

The involvement of a significant crustal component in the petrogenesis of the medium grained phase of the Botham stock is not consistent with relatively high Sr abundances, high $\text{Na}_2\text{O}/\text{K}_2\text{O}$, the absence of significant Eu anomalies and the depleted mantle-type Nd isotopic signature. One of ten zircons analyzed as part of the U-Pb dating program (Davis et al., 1998) had an anomalously old $^{206}\text{Pb}/^{207}\text{Pb}$ age of 2701 Ma and is also distinct from most of the other zircons in terms of its Th/U ratio. Only a small number of zircons were recovered from this sample and it is possible that most of the zircons represent contamination. These observations indicate that the Botham stock has interacted to some degree with slightly older crustal rocks, although this interaction does not appear to have significantly modified the bulk compositional characteristics of the pluton.

Many of the geochemical characteristics of the medium grained phase of the Botham stock are comparable to those described as part of this report as well as by others (e.g., Martin, 1987, Drummond and Defant, 1990) for which a TTG origin is interpreted. The most diagnostic characteristics include high Na/K, high abundance of Sr, fractionated REE with HREE depletion, negligible Eu anomalies and mantle isotopic signature. The apparent extreme REE fractionation ($\text{Ce}_\text{N}/\text{Yb}_\text{N} = 65$) is somewhat anomalous and is in part a function of extreme HREE depletion to near detection limit.

The biotitic nature and low Ni, Cr and Mg# of the medium grained phase of the Botham stock are inconsistent with this unit being a primary sanukitoid melt, and are atypical of fractionated members of the sanukitoid suite. The extremely magnesian nature of the biotite could be consistent with this mineral having equilibrated with a more primitive or more oxidized magma but other explanations (e.g., increasing $f\text{O}_2$ due to loss of H_2O (Wones and Eugster, 1965) or biotite being of hydrothermal origin (Beane, 1974)) are also possible in the absence of more detailed study.

White River Pluton

The White River pluton, as discussed in a previous section, is a steeply dipping tabular unit with a more mafic northern portion and more felsic southern portion which may indicate that the unit is an early differentiated sill that was deformed along with the enclosing supracrustal rocks. This section evaluates the differentiated sill hypothesis.

Two samples from the mafic northern portion (base?) of the unit are monzodioritic with amphibole dominated mafic minerals comprising approximately 50 percent of the rock. Two samples from the central and southern (top?) portion of the intrusion are monzodioritic to quartz monzodioritic with a lesser abundance of mafic minerals (color index ~ 30 with a minor amount of chloritized biotite along with predominant amphibole and containing a small amount (3-6 percent) of quartz). Trace primary accessory minerals throughout the unit include sphene, apatite and a complex opaque assemblage including both oxides and sulphides. Alteration is generally moderately strong with

strong to intense saussuritization of plagioclase and chloritization of biotite. Secondary carbonate is notable locally, particularly in the northern portion of the unit.

In order to evaluate variation through the unit, various mineralogical and geochemical parameters were plotted against UTM northing of the sample selection site. Since the unit strikes east and the samples were collected along a narrow north trending corridor, this results in a qualitative profile (not corrected for possible dip of the unit) with the more mafic portion (base?) of the unit on the right side of the graphs (Figure 48). A number of general observations follow:

- ◆ The mineralogical and geochemical data indicate a major compositional contrast between the northern mafic portion of the unit and the southern more felsic portion of the unit.
- ◆ Although some variables display a progressive variation trend from the north to the south side of the unit, many variables display a stepped variation. The limited number of samples does not allow this possible relationship to be addressed further.
- ◆ The two felsic samples are mineralogically similar as are the two mafic samples. The much lower amphibole abundance in the felsic samples is compensated for by increased abundance of plagioclase and, to a lesser extent, quartz. Microcline abundance does not appear to vary systematically through the unit.
- ◆ Mineral chemical variation includes plagioclase from the two more southerly (felsic) samples being more sodic (An_{24-31}) as compared to that in the more mafic portion of the unit (An_{39}) and there is a progressive increase in the FeO/MgO ratio of amphiboles.
- ◆ Most major elements show a stepped increase (SiO_2) or decrease (FeO, MgO) going from the mafic to the felsic portions of the unit. The trends for CaO, Na_2O and K_2O are more erratic.
- ◆ Sr and Ba increase towards the felsic side of the unit.
- ◆ Cr, V, Ni and Cr decrease towards the felsic side of the unit.
- ◆ The abundance of REE (Figure 49) decreases slightly towards the felsic side of the unit although the degree of REE fractionation remains relatively constant throughout. The magnitude of the weak negative Eu anomaly is greatest in the mafic portions of the unit.

The whole rock major element, and aspects of the mineral chemical, variation is broadly consistent with, but not diagnostic of, the mafic and felsic portions of the unit being related by crystal fractionation. The trace element variation, however, suggests that this is unlikely. The significant change in Mg# from the mafic to felsic portions of the unit require that, if the samples are related by crystal fractionation, there must be a significant ferromagnesian mineral component (most likely amphibole) to the fractionating mineral phases. The near uniformity of Yb and REE fractionation within the unit is difficult to reconcile with amphibole fractionation as this mineral would be expected to preferentially deplete the HREE and lead to more fractionated REE patterns which is not observed. This objection could be overcome if clinopyroxene were the fractionating

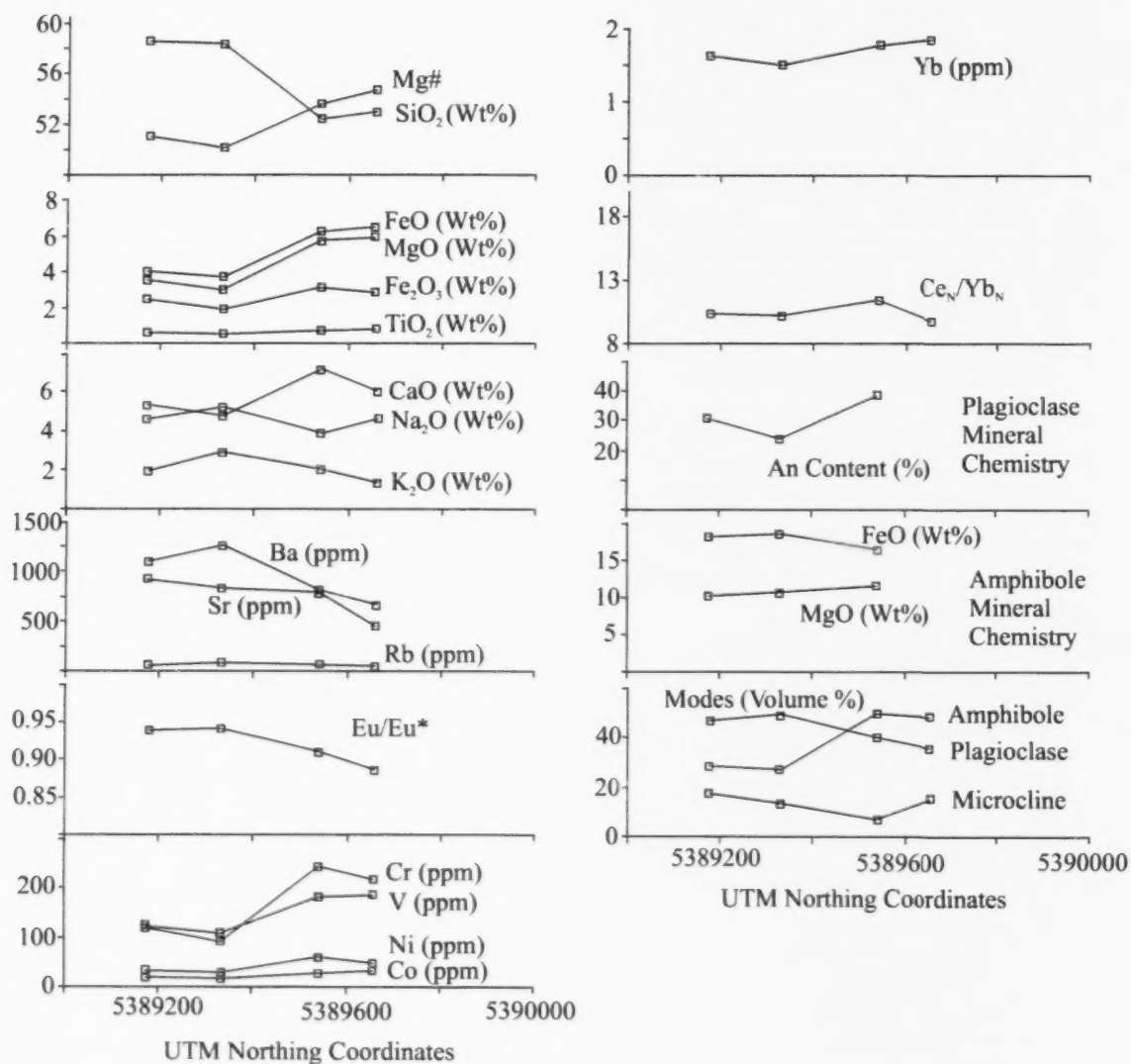


Figure 48. Summary of variation in selected geochemical and mineralogical parameters within the White River pluton. The abscissa is in UTM northing coordinates which is used as a proxy for height in this east trending unit. The more mafic (base?) portion of the unit is on the right side of each of the graphs. Unless otherwise noted, all of the data pertains to whole rock chemistry.

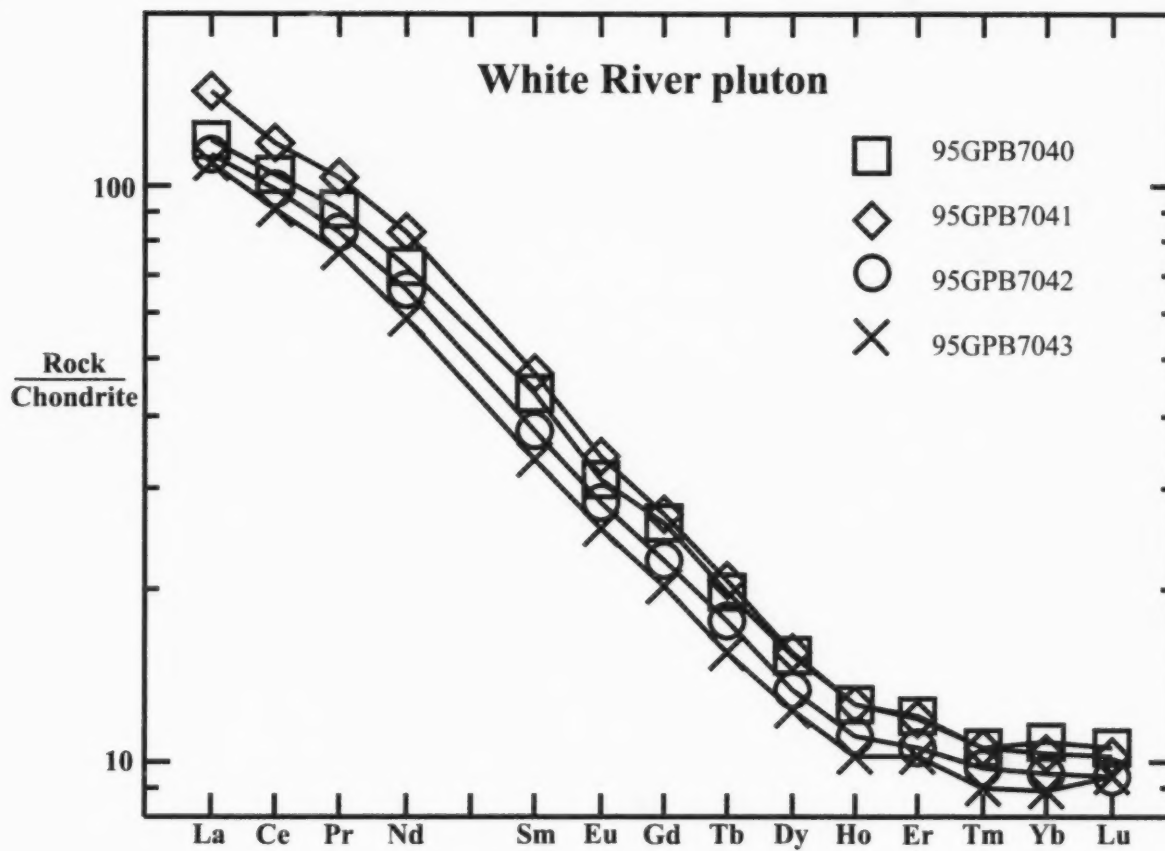


Figure 49. Chondrite normalized REE spectra for the White River pluton. Chondrite normalization values are from Sun and McDonough (1989).

primary magmatic phase and all of the amphibole were a secondary replacement of original pyroxene, but petrographic evidence suggests that amphibole is a primary magmatic phase and there is no evidence for any original pyroxene. The other main mineral that might be expected to be involved in any fractional crystallization process is plagioclase. A significant plagioclase fractionation component is inconsistent with the higher Sr abundances and less pronounced negative Eu anomalies that characterize the more felsic component of the unit. Although the limited amount of data precludes a more detailed analysis, it is provisionally concluded that the mafic and felsic portions of the White River pluton are not related by crystal fractionation. The proximity of these phases and similarity of their REE patterns may indicate that they are genetically related in some other way.

As discussed above, most of the geochemical characteristics of these samples support a bimodal character. Relative to the more mafic samples, the more felsic samples are, for example, characterized by higher SiO₂ (58% vs 53%) and Ba (~1200 ppm vs 800 ppm) and lower MgO (~3.5% vs 6%), Cr (~125 ppm vs 225 ppm), Ni (~35 ppm vs 60 ppm). These two groups of samples are also similar in certain respects. K₂O abundance (1.5-3.1%) is relatively high for rocks with these SiO₂ abundances and contributes to a mildly alkaline character. The more felsic samples have slightly lower REE abundances but display remarkable similarity in their degree of fractionation (C_{eN}/Y_{bN} ~10-11) and general pattern of enrichment. The also have comparable depleted mantle-type Nd isotopic characteristics ($\epsilon_{Nd}^{2691Ma} = +2.2$ for a mafic sample and $\epsilon_{Nd}^{2691Ma} = +2.5$ for a felsic sample).

The limited number of samples and uncertainties regarding their interrelationship preclude a comprehensive analysis of the petrogenesis of this unit. The relatively mafic, quartz-poor, strongly metaluminous and mildly alkaline character together with the relatively high Mg# and Sr, Ni and Cr abundances and mantle-type isotopic signature precludes significant involvement of older continental crust in the generation of this unit. The general character (mafic, quartz-poor nature) as well as some aspects of the geochemistry (strongly metaluminous, mildly alkaline character and high Mg# and Ni and Cr abundances) of these rocks are also atypical of TTG suite plutons. These same characteristics together with the fractionated and overall high abundances of REE, are similar in most respects to those characterizing sanukitoid suite plutons.

Terrace Bay Batholith

The Terrace Bay batholith intrudes the Terrace Bay – Schreiber greenstone belt to the west of the Hemlo greenstone belt. Although now separated by the Proterozoic Coldwell alkalic intrusion, these greenstone belts were likely contiguous and genetically related. Marmont (1988) studied this batholith and concluded that it is a medium grained, relatively fresh and undeformed granodiorite pluton that contains numerous Cu-Mo and Au mineral occurrences. Some of this mineralization is interpreted by Marmont to be related to residual fluids derived in the late stages of crystallization of the batholith. Several samples were selected from this batholith in order to compare a mineralized

pluton with some unmineralized, otherwise similar plutons from the Hemlo greenstone belt area.

Petrology and Mineralogy of Main Phases

Two samples of the main granodiorite phase agree closely with the general mineralogy as described by Marmont (1984). The main phase is a hornblende-biotite granodiorite (Figures 3 and 4). Plagioclase is subhedral and in the one sample analyzed in detail was found to fairly consistently display normal zoning (An_{39-30}). Plagioclase is weakly to moderately altered to a fine-grained mixture of white mica, epidote and carbonate with the distribution of the alteration commonly controlled by zoning. Microcline is microperthitic and includes both fine intergranular grains and larger, poikilitic subhedral megacrysts.

Amphibole and biotite are both primary magmatic mafic mineral phases with the former being approximately three times as abundant as the latter. Amphibole classifies as magnesiohornblende and is among the most magnesian ($Mg/Mg+Fe = 0.7$) of any amphiboles from plutons in the Hemlo greenstone belt area. Biotite is weakly to moderately altered to chlorite. Biotite is similarly anomalously magnesian in comparison to that from other plutons associated with the Hemlo greenstone belt (Figure 46). Single phase, oxide octahedra are uniformly nearly pure magnetite. Subhedral to euhedral epidote, rarely displaying simple twinning, is a primary magmatic phase. Other primary accessory minerals include sphene, apatite and zircon.

Hornblende-biotite diorite enclaves are a minor, but widely distributed component of the Terrace Bay batholith. Although mafic minerals are more abundant and quartz and microcline less abundant, compared with the host granodiorite, many of the textural relationships are similar to those described above for the predominant granodiorite phase.

Geochemical Characteristics

The chemical composition of the two samples lies within the ranges identified for the spectrum of later plutonic group units associated with the Hemlo greenstone. The main granodiorite phase is subalkaline and mildly metaluminous. Other notable geochemical characteristics include relatively high HREE and Y abundances that results in weakly (relative to most plutons in the Hemlo greenstone belt area) fractionated REE patterns (Figure 50). The age of the Terrace Bay batholith is unknown, but presuming it to be generally comparable in age to the plutons associated with the Hemlo greenstone belt, but it appears to have a depleted mantle isotopic signature ($\epsilon_{Nd}^{2686Ma} = +2.3$).

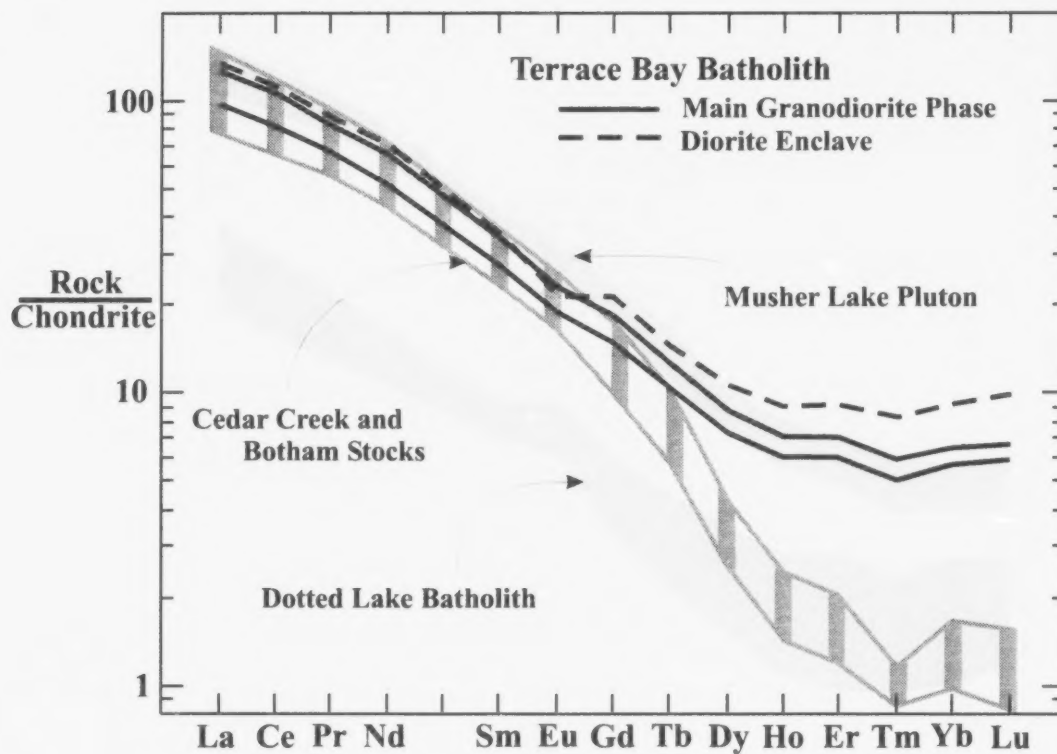


Figure 50. Chondrite normalized REE spectra of the Terrace Bay batholith compared to those of the Musher Lake pluton, Dotted Lake batholith and the Cedar Creek and Botham stocks. Chondrite normalization values are from Sun and McDonough (1989).

Relative to plutons with generally similar major element geochemical characteristics (e.g., Cedar Creek stock and medium grained phase of Botham stock), the Terrace Bay batholith is distinctive by virtue of its high Mg# and high abundance of Ni, Cr, Yb and Y. It is similar to the Musher Lake pluton with respect to most trace element abundances although the Terrace Bay batholith is less mafic and consequently has somewhat higher SiO₂ and lower Al₂O₃ and TiO₂ (Figures 23 to 37). The petrogenesis of this pluton may be similar to the Musher Lake pluton but there is insufficient data to justify a detailed analysis.

Granitoid Rocks associated with the Hemlo Greenstone Belt: A Regional Perspective

The foregoing discussion presents observations and interpretations on specific plutons spatially associated with the Hemlo greenstone belt. Most of the plutons differ to varying degrees with respect to other plutons in the area in terms of various aspects of their petrology, geochemistry and petrogenesis although certain groupings of plutons exhibit some similarities. The purpose of this section is to discuss the overall characteristics of intermediate to felsic plutonism associated with the Hemlo greenstone belt leading to a discussion of the evidence for secular evolution in granitoid magmatism and its tectonic significance.

Tectonic Setting

The relationships and radiometric age determinations described above indicate that intermediate to felsic intrusive rocks associated with the Hemlo greenstone belt can be broadly subdivided into 1) pre-D₁, possibly syn-volcanic units, 2) post-D₁, syn-D₂ units and 3) post-D₁, syn- to post-D₂ units.

The foliated to gneissic units in the Black-Pic and Pukaskwa batholiths, together with the Dotted Lake batholith are as old or older than some of the volcanic and sedimentary rocks of the greenstone belt. All of these units are characterized by the presence of a well-developed fabric that is locally conformable to the fabric within the greenstone belt and to which it may be temporally and genetically related. The Moose Lake porphyry is interpreted to be syn-volcanic on the basis of field relationships and consequently carries the same fabric as adjacent volcanosedimentary units. These units have all been deformed subsequent to the imposition of the D₁ deformational fabric by the D₂ regional folding event.

Some of the larger, discrete, massive to foliated plutons are interpreted to post-date D₁ and be syn- D₂ (Cedar Lake pluton, Heron Bay pluton) or syn-to post- D₂ (Gowan Lake pluton, Musher Lake pluton) on the basis of the following observations and interpretations:

- 1) None of these plutons carries a strong penetrative fabric of the type observed in the pre-D₁ units described above or the volcanosedimentary rocks of the greenstone belt. Only the Cedar Lake pluton has a clear superimposed

tectonic fabric but this is much more weakly developed than other observed D_1 fabrics. This tectonic fabric is well developed only in the southwest portion of the pluton. Cedar Lake pluton fabric could be either pluton induced or a regional D_2 fabric. Many of these plutons (notably Heron Bay and Gowan Lake plutons) have no discernable penetrative deformational fabric and locally preserve magmatic flowage fabrics (Gowan Lake pluton).

- 2) The Heron Bay and Musher Lake plutons both exhibit crosscutting relationships (Plates 7 and 10) with respect to the strong regional penetrative fabric of the greenstone belt. The penetrative fabric in volcanosedimentary inclusions occurring within the Musher Lake pluton are locally folded.
- 3) The contacts of many of the plutons mimic the pattern of regional folding of the greenstone belt and some of them appear to have the form of laccoliths or phacoliths within the cores of regional scale folds (Figure 2). Magmatic flowage fabrics are also constrained to be sub-parallel to the boundaries of the plutons.

These observations are interpreted to indicate that these discrete, massive to foliated plutons were emplaced following the imposition of regional penetrative fabrics on the greenstone belt and earlier plutons and synchronous with the development of regional scale folding of the greenstone belt. Although the plutons may core regional scale fold structures, they are not interpreted to have been the causal agent of folding but rather to have assumed their geometric configuration to accommodate the folding of the greenstone belt.

These interpretations, together with constraints on the ages of the plutons, suggest a very rapid tectonic evolutionary development for the Hemlo greenstone belt. A metasedimentary rock from the Heron Bay area with detrital zircons as young as 2693 Ma (see Davis et al., 1998) and the 2697 Ma Dotted Lake pluton pre-date the earliest deformation recognized in the greenstone belt. Numerous plutons, generally constrained to an age range from 2680 to 2690 Ma, are interpreted to post-date the imposition of a strong D_1 penetrative fabric and be broadly synchronous with regional folding of the greenstone belt and D_1 fabric. This suggests that the Hemlo greenstone belt evolved from its depositional stage to near its final tectonometamorphic configuration within 10 to 20 million years.

Depth of Emplacement

No studies have specifically addressed the P-T conditions attendant with emplacement of the plutons intruding the greenstone belt. Most studies of metamorphism of the Hemlo greenstone belt have focused on the Hemlo deposit area (Burk et al., 1986; Kuhns et al., 1994, Powell et al., 1999) or other geographically restricted segments of the belt (Pan and Fleet, 1993). It should be noted that the regional metamorphic grade increases to the east (Jackson, 1998), hampering extrapolation of the significance of these more detailed studies to the regional scale.

Powell et al. (1999) summarized these detailed studies and note that all concluded that an earlier, moderate pressure (0.6-0.8 Gpa) mineral assemblage is overprinted by a lower pressure (0.4-0.5 Gpa) mineral assemblage although there is some doubt as to whether this represents two discrete metamorphic events or a single protracted event. U-Pb ages (Corfu and Muir, 1989b) and $^{40}\text{Ar}/^{39}\text{Ar}$ mineral ages (Grant, 1995) suggest slow, post-peak metamorphic cooling. Corfu and Muir (1989b) suggested that titanite ages of 2678 to 2676 Ma may correspond to the timing of amphibolite-facies metamorphism, however the evidence they cite is only permissive, rather than indicative, of this interpretation. Others have advocated generally similar timing of regional metamorphism (Kuhns et al., 1994; Powell et al., 1999) for the Hemlo deposit area. The evidence cited by the above authors is permissive of the interpretation that amphibolite-facies metamorphic conditions may have prevailed at 2676-2678 Ma but the metamorphic paragenesis of titanites that were dated is unconstrained (T.L. Muir, personal communication, 1999) and consequently, the absolute timing and duration of regional metamorphism is poorly constrained. The Heron Bay pluton locally transects a fabric defined by an amphibolite-facies mineral assemblage indicating that at least the earliest component of this metamorphism pre-dates the emplacement of this pluton (~2690 Ma). The Heron Bay pluton is itself only slightly younger than many of the metamorphosed supracrustal rocks (Davis et al., 1998). Consequently, the interpretation favored here is that amphibolite-facies metamorphism (multiple discrete events or, more probably, a single protracted event) commenced within several million years of the deposition of the greenstone belt and persisted through a time interval of at least 15 Ma that generally corresponds with the emplacement of the later plutonic group.

Many of the plutons associated with the Hemlo greenstone belt contain the mineral assemblage quartz - k-feldspar - plagioclase - hornblende - biotite - Fe-Ti oxide - sphene and are therefore suitable for the application of the aluminum in hornblende geobarometer (Hammarstrom and Zen, 1986; Hollister et al., 1987). Pressures are calculated as described in Stone (2000) using the revised expression of Anderson and Smith (1995) incorporating the amphibole-plagioclase thermometer of Holland and Blundy (1994). Amphibole formulas were recalculated by the method of Leake et al. (1997). The resulting pressure estimates are discussed in terms of the field relationships of the plutons with respect to metamorphism in adjacent country rocks and their geographic and temporal distribution.

The pressures derived from application of the Al in hornblende geobarometer are summarized in table 5. Amphibole compositions were found to be uniform within individual grains and thin sections and averages of 6 to 19 analyses per thin section were used to calculate the pressures. The estimated pressures are generally comparable to the pressures ascribed to the overprinting lower pressure metamorphism characterizing the greenstone belt (Powell et al., 1999) although the pressures estimated for the youngest of the plutons (Fourbay Lake, Gowan Lake and Musher Lake plutons) is somewhat lower. This is consistent with the interpretation that amphibolite-facies regional metamorphic conditions prevailed throughout much of the interval over which late plutons were emplaced. The lower pressures of the youngest plutons may indicate that decompression

Table 5. Average hornblende analyses and pressure estimates for samples with mineral assemblages suitable for application of the aluminum in hornblende geobarometer. Methods are discussed in the text.

Unit	Cedar Lake Pluton					Dike	Heron Bay Pluton				
Sample	7004A	7018A	7032	7033A	7067	7031	7071	7096	7099	7152	
Analyses	11	6	10	8	8	9	7	19	12	9	
X ^{ab} _{plag}	0.70	0.73	0.72	0.70	0.71	0.73	0.73	0.72	0.70	0.67	
SiO ₂	43.12	45.78	41.35	43.74	44.47	42.28	42.92	44.07	41.69	42.89	
TiO ₂	0.79	0.64	0.53	0.72	0.86	0.54	0.61	0.69	0.62	0.92	
Al ₂ O ₃	9.65	8.05	11.07	9.79	9.20	10.22	10.00	9.19	10.71	10.78	
Cr ₂ O ₃	0.04	0.03	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.04	
FeO*	19.92	17.40	22.08	19.74	18.70	21.10	20.92	19.54	21.13	19.48	
MnO	0.35	0.39	0.39	0.35	0.35	0.33	0.38	0.37	0.30	0.34	
MgO	9.36	11.54	8.03	9.58	10.16	8.75	8.75	9.72	8.42	9.29	
CaO	11.46	11.50	11.42	11.42	11.57	11.47	11.46	11.50	11.46	11.24	
Na ₂ O	1.44	1.37	1.56	1.44	1.34	1.37	1.40	1.40	1.43	1.60	
K ₂ O	1.20	0.92	1.50	1.14	1.05	1.29	1.18	0.91	1.33	1.36	
F	0.22	0.26	0.35	0.26	0.21	0.20	0.30	0.24	0.31	0.19	
Cl	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01	
Total	97.55	97.88	98.29	98.18	97.94	97.57	97.95	97.65	97.42	98.13	
Si	6.55	6.82	6.31	6.58	6.67	6.44	6.52	6.65	6.38	6.47	
Al ^{iv}	0.27	0.23	0.30	0.32	0.30	0.28	0.31	0.28	0.32	0.39	
Ti	0.09	0.07	0.08	0.08	0.10	0.06	0.07	0.08	0.07	0.10	
Fe ³⁺	0.48	0.42	0.65	0.47	0.39	0.64	0.54	0.47	0.60	0.39	
CaB	1.86	1.83	1.87	1.84	1.86	1.87	1.86	1.86	1.88	1.82	
NaB	0.07	0.09	0.07	0.08	0.07	0.07	0.07	0.08	0.06	0.10	
(Na+K)A	0.58	0.48	0.68	0.55	0.52	0.59	0.57	0.51	0.62	0.63	
Mg/(Mg+Fe)	0.51	0.59	0.46	0.52	0.54	0.49	0.48	0.52	0.48	0.50	
T (C)	751	718	789	729	716	757	736	728	766	735	
P (kB)	4.04	3.21	4.25	4.48	4.21	4.36	4.60	4.06	4.58	5.18	

Unit	Gowan Lake Pluton				Fourbay Lake Pluton	Cedar Creek Stock	Musher Lake Pluton	Pukaskwa Batholith	Black-Pic Batholith	
Sample	7175	7183	7233	7250	7239	7240	7297	7075	7255	7213
Analyses	12	11	10	10	7	14	13	12	9	8
X ^{ab} _{plag}	0.93	0.81	0.84	0.72	0.72	0.82	0.74	0.62	0.71	0.59
SiO ₂	46.22	44.84	45.96	45.09	44.89	44.62	42.79	43.48	43.35	41.45
TiO ₂	1.29	1.43	1.14	1.41	1.37	1.43	0.52	0.97	0.56	0.79
Al ₂ O ₃	7.94	9.04	7.91	8.26	8.33	8.90	10.21	9.85	10.06	11.63
Cr ₂ O ₃	0.03	0.00	0.02	0.02	0.01	0.01	0.02	0.03	0.02	0.01
FeO*	16.65	17.21	16.73	17.98	18.05	17.69	20.49	19.34	19.67	21.68
MnO	0.42	0.46	0.44	0.49	0.54	0.46	0.43	0.39	0.52	0.54
MgO	11.52	10.85	11.64	10.64	10.58	10.62	9.13	9.75	9.43	7.54
CaO	11.44	11.43	11.42	11.20	11.20	11.45	11.44	11.58	11.50	11.45
Na ₂ O	1.42	1.54	1.36	1.59	1.60	1.52	1.38	1.38	1.45	1.17
K ₂ O	0.89	1.10	0.90	1.07	1.06	1.07	1.36	1.15	1.24	1.44
F	0.14	1.54	0.16	0.23	0.22	0.16	0.34	0.16	0.27	0.13
Cl	0.02	0.03	0.02	0.03	0.06	0.02	0.00	0.00	0.01	0.01
Total	97.95	99.47	97.69	98.01	97.70	97.95	98.12	98.08	98.07	97.83
Si	6.86	6.70	6.84	6.76	6.73	6.69	6.48	6.54	6.54	6.33
Al ^{iv}	0.25	0.29	0.23	0.22	0.21	0.26	0.30	0.28	0.33	0.42
Ti	0.14	0.16	0.13	0.16	0.16	0.16	0.06	0.11	0.06	0.09
Fe ³⁺	0.24	0.24	0.29	0.27	0.29	0.26	0.59	0.48	0.49	0.59
CaB	1.82	1.83	1.82	1.80	1.81	1.84	1.86	1.87	1.86	1.87
NaB	0.11	0.10	0.10	0.12	0.11	0.09	0.08	0.07	0.08	0.07
(Na+K)A	0.47	0.55	0.47	0.54	0.56	0.56	0.59	0.55	0.59	0.56
Mg/(Mg+Fe)	0.58	0.56	0.59	0.55	0.55	0.55	0.51	0.53	0.52	0.44
T (C)	665	748	734	731	742	757	739	773	728	759
P (kB)	3.68	3.51	2.87	3.24	3.13	3.26	4.69	3.64	4.74	5.41

had commenced by the time of their emplacement. Amphibolite-facies conditions may still have prevailed, however, due to the introduction of heat associated with the relatively voluminous late plutons.

The plutons for which pressure estimates are available range from the later, more massive plutons to earlier, foliated tonalitic rocks. These units range in age from approximately 2720 to 2677 Ma. The earliest units (~2720 Ma) for which thermobarometric data is available predate the imposition of a fabric that is defined by a mid- to upper amphibolite grade, peak metamorphic mineral assemblage. The Heron Bay pluton (~2688 Ma) is locally observed to crosscut the fabric defined by peak metamorphic mineral assemblages and the Musher Lake pluton (~2679 Ma) contains inclusions with folded metamorphic fabric.

Metamorphic grade within the Hemlo greenstone belt is non-uniform with metamorphic grade increasing from west to east as well as towards some of the granite – greenstone contacts (Jackson, 1998). The estimated pressures derived for the plutons investigated as part of this study can be used to test the hypothesis that this regional variation might involve late tilting to expose deeper levels of the crust in the east. In general, the estimated pressures do not appear to vary systematically with their location (Figure 51) and in particular there is no evidence for a systematic increase in pressure to the east (Figure 52).

The plutons for which pressure estimates are available span an interval of approximately 43 Ma from approximately 2720 to 2677 Ma. Most of the data are from the later plutonic group which spans a more restricted time interval (~2690 to 2677 Ma) during which, as discussed above, the greenstone belt rapidly evolved from its depositional stage to near its final tectonometamorphic configuration. The pressures derived from the aluminum in hornblende geobarometer appear to correlate in a general way with the age of the plutonic units (Figure 52). A similar tendency for decreasing pressures with decreasing age of emplacement has been noted in the Berens River subprovince of the western Superior Province (Stone, 2000). The lower pressures indicated for the youngest of the plutons associated with the Hemlo greenstone belt, suggest that the initial stages of exhumation may have accompanied late pluton emplacement. A working hypothesis consistent with the data and interpretations discussed above is that late plutonism, regional folding and attendant medium-grade metamorphism resulted in uplift (mountain building) leading to erosion and decompression. The sedimentary record of such a process is apparently not preserved in the Hemlo greenstone belt but may be represented in metasedimentary rocks of the Manitouwadge greenstone belt and Quetico subprovince which were deposited subsequent to 2690 Ma (Zaleski et al., 1997).

Role of Crustal Recycling/Contamination

The possible role of crustal contamination and/or crustal recycling has been addressed for each of the units separately above. An overall assessment of the possible significance of this process is offered here.

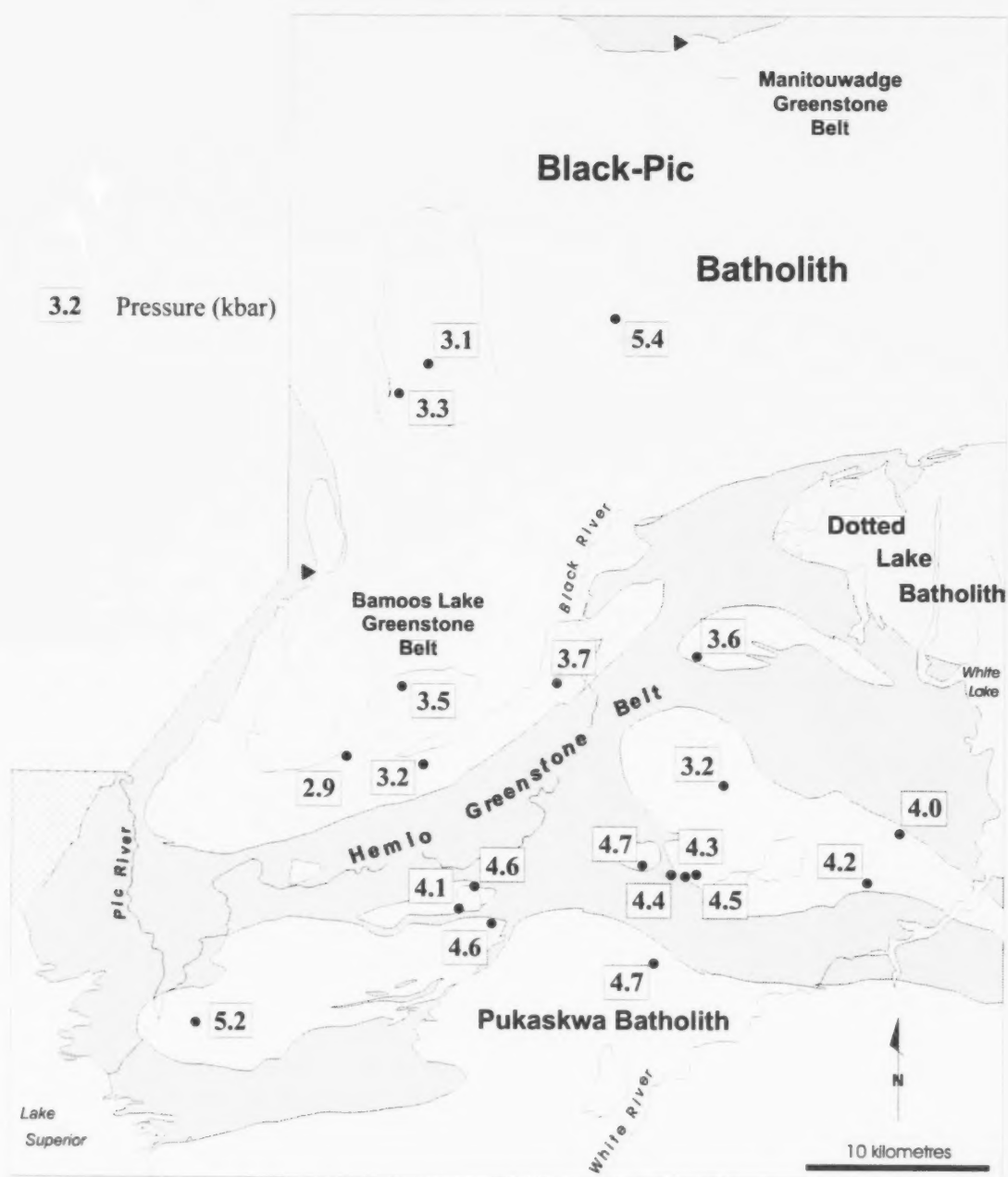


Figure 51. Aluminum in hornblende geobarometer pressure estimates in relation to the generalized geology of the Hemlo greenstone belt. Pressure estimates are based on the revised expression of Anderson and Smith (1995).

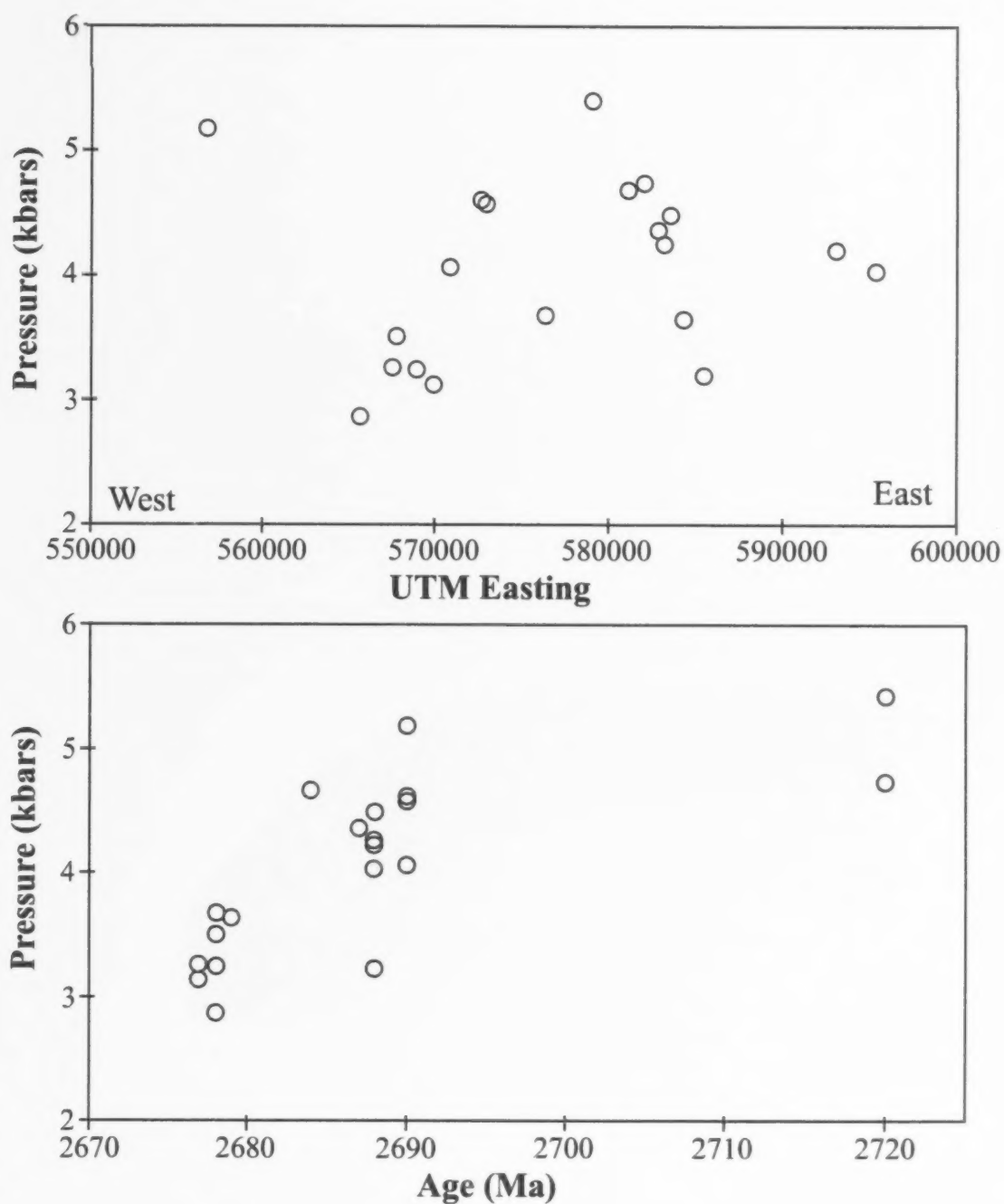


Figure 52. Variation in pressure as determined from application of the Al in hornblende geobarometer as a function of a) UTM easting and b) age of emplacement. UTM easting is used to indicate location to evaluate distribution of pressures in relation to the eastward increase in regional metamorphic grade (Jackson, 1998). Age of emplacement is based on results from U-Pb zircon geochronology discussed elsewhere in the text.

The most compelling evidence for some degree of interaction with pre-existing crust is the presence in a few of the units of inherited zircons that record ages older than the interpreted crystallization age of the pluton (Table 2). In general, the ages of inherited zircons correlate with ages determined for either the greenstone belt or the tonalite gneiss component of the belt bounding batholiths. The only significantly older zircon ages reported are those for the Moose Lake porphyry (2772 Ma; Corfu and Muir, 1989a). In some cases (e.g., feldspar porphyry dike), the intrusions are small, with limited amounts of zircon and there is a high probability that the zircons may be accidental inclusions incorporated near the site of crystallization. In other cases (e.g., sample from western portion of the Heron Bay pluton), the samples are from the interior of relatively large plutons well removed from any exposed contacts with country rock and the zircons have likely been transported some distance in the magma. Most units apparently lack inherited zircons and may not have interacted to any appreciable extent with older rocks.

The Nd isotopic signature of intermediate to felsic intrusive rocks associated with the Hemlo greenstone is restricted to a narrow range ($\epsilon_{Nd} = +1.7$ to $+3.2$) comparable to, or slightly lower than, estimates for Late Archean depleted mantle (Figure 53). These results suggest that it is unlikely any of these rocks are products of crustal melting of, or have been significantly modified by interaction with, significantly older continental crust. These data, in themselves, cannot rule out minor involvement of significantly older crust or a major role for slightly older felsic crust. One interpretation of the tendency to slightly less radiogenic signatures in the younger units could be increased crustal contamination or even wholesale crustal melting of 2720 Ma tonalitic crust but this is considered unlikely on other grounds discussed below. Alternative interpretations for the slight decrease in ϵ_{Nd} include derivation from distinct mantle sources at different times, derivation of all units from a single depleted mantle source that was metasomatically enriched in LREE at 2720 Ma or a change from slab to mantle melting with time.

A variety of geochemical characteristics are inconsistent with the involvement of anything other than a volumetrically insignificant crustal component in the petrogenesis of granitoid rocks associated with the Hemlo greenstone belt. Melting of normal continental crust (granodiorite to tonalite bulk composition) would be expected to produce moderately peraluminous, relatively quartz-rich melts characterized by low Mg#, prominent Eu anomalies and Ca and Sr depletion due to retention of calcic plagioclase in the residue (c.f., Lount Lake batholith, Beakhouse and McNutt, 1991). No units associated with the Hemlo greenstone belt display these characteristics. The youngest units with the least radiogenic Nd that would be permissive of the most crustal involvement are very strongly metaluminous, enriched in CaO with comparatively low SiO_2 and have Mg#, Ni and Cr comparable to or greater than that characterizing most Archean tonalites.

The observations discussed above are interpreted to indicate that, whereas there was some interaction with older rocks facilitating incorporation of older zircon in some units, there is little evidence to suggest that magmas were derived by melting of, or significantly modified by interaction with, pre-existing felsic crust. The ages of inherited zircons are generally comparable to the ages of supracrustal rocks within the greenstone

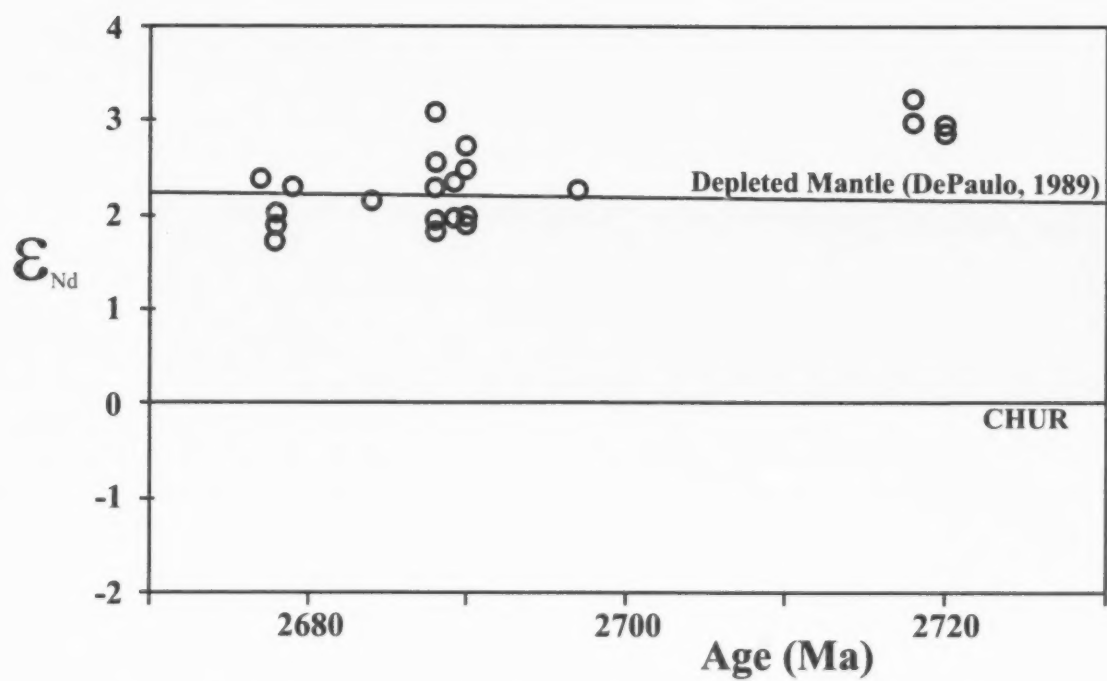


Figure 53. Nd isotopic evolution diagram for plutons associated with the Hemlo greenstone belt in relation to the depleted mantle model of DePaulo (1981).

belt and the tonalite gneiss component of the belt-bounding batholiths which are interpreted to structurally underlie the greenstone belt. It is probable that the bulk composition of the magmas now represented by the plutons associated with the Hemlo greenstone belt were not appreciably modified by interaction with the crust into which they were emplaced.

$f\text{H}_2\text{O}$ and $f\text{O}_2$ of Late Plutons

Intrinsic properties of magmas such as $f\text{H}_2\text{O}$ and $f\text{O}_2$ exert a major influence on the ultimate nature of the resultant crystalline rock. In particular, $f\text{O}_2$ is regarded to be a first order control on the ability of magmas to transport, and allow for the concentration of, metals (Carroll and Rutherford, 1985; Hattori, 1987). These intrinsic properties were not evaluated comprehensively as part of this study, however some of the observations made place some constraints on the nature of these variables.

Intermediate to felsic magmas typically have water contents in the range of 1 to 7 % (Clemens, 1984). The presence of hydrous primary magmatic minerals (principally biotite and amphibole) in all of the plutons associated with the Hemlo greenstone belt indicates that all crystallized from hydrous magmas. Experimental evidence indicates that hornblende-bearing magmas must contain at least 3 to 4 percent H_2O in order to stabilize this phase (Naney, 1983). Although granitic, pegmatitic and aplitic dikes cut some of the plutons, these are minor and not clearly genetically related to the plutons in which they occur. The absence of widespread, co-magmatic, pegmatitic zones within the plutons associated with the Hemlo greenstone belts suggests that they did not evolve to water saturation and exsolve a separate hydrous fluid or vapor phase during the main part of their crystallization interval at the exposed crustal level. A variety of widely observed characteristics do, however suggest that a magmatic volatile phase was liberated during the final stages of crystallization and interacted with the crystalline component. These characteristics include formation of late magmatic microcline megacrysts with attendant development of myrmekite and replacement of plagioclase, saussuritization of plagioclase and chloritization of biotite. The latter two alteration phenomena could also be caused by hydrothermal alteration but this is considered unlikely because of the uniformity and ubiquity of this style of alteration and the absence of any obvious porosity/ permeability control. It is most likely that this style of alteration is an autometasomatic effect related to the interaction of a magmatic volatile phase, exsolved during the latest stages of crystallization, with the primary magmatic minerals. The common presence of minor calcium carbonate along with epidote and white mica in the alteration product of plagioclase feldspar suggests that CO_2 was also a component of the magmatic volatile phase that reacted with the anorthite component of plagioclase feldspar.

Some gold mineralization in the Superior Province, including the Hemlo deposit, is interpreted to be genetically related to oxidized hydrothermal fluids (Cameron and Hattori, 1987; Cameron and Carrigan, 1987). These authors also regard intrinsically oxidized magmas as the most likely source of such fluids and discuss evidence that the

Cedar Creek stock (referred to by these authors variously as the Cedar Lake stock or part of the Cedar Lake pluton) is a product of such a highly oxidized magma.

Some of the observations made as part of this study are consistent with the interpretation that many of the plutons associated with the Hemlo greenstone belt crystallized from relatively oxidized intermediate to felsic magmas. Although some of these observations (Table 6) are only semi-quantitative and secondary processes may have played an important role in some cases, they also suggest that magmas may have become more intrinsically oxidized with time.

The fO_2 of a magma is mainly buffered by Fe^{2+}/Fe^{3+} and consequently the measured whole rock $Fe_2O_3/(Fe_2O_3+FeO)$ ratio may be used to constrain this parameter. Unfortunately, both geological and analytical problems complicate this interpretation. The principal geological problem is the possibility that the ferric/ferrous ratio may be modified by subsolidus reactions and it is probable that some of the scatter in measured $Fe_2O_3/(Fe_2O_3+FeO)$ reflects secondary alteration. The analytical method employed to determine $Fe_2O_3/(Fe_2O_3+FeO)$ (total iron by XRF with wet chemical determination of FeO) may secondarily oxidize the sample and limit the reliability of the analysis although this problem can be addressed by careful analysis (Lalonde et al., 1998). These potential complications notwithstanding, the general coherence of the results within individual units suggests that these problems may be minimal and the results may be cautiously interpreted to be reflective of the ferric/ferrous iron ratio of the magma. The $Fe_2O_3/(Fe_2O_3+FeO)$ ratio of most of the late plutons falls mostly in the range 0.4 to 0.5. These values (converted to atomic proportions) are generally comparable to the more oxidized Australian I-type granites (Takahashi et al., 1980). The medium grained phase of the Botham pluton and the Cedar Creek stock are somewhat anomalous, having $Fe_2O_3/(Fe_2O_3+FeO)$ ratios in excess of 0.5 (averages, 0.60 and 0.55, respectively). The results for the Cedar Creek stock are consistent with the results of a more exhaustive study of the redox state of this pluton that identified its highly oxidized character with an inferred oxygen fugacity midway between the hematite-magnetite and nickel-nickel oxide buffers (Cameron and Carrigan, 1987).

Magnetic susceptibility has been used as a redox indicator to distinguish "reduced" S-type or ilmenite-series granitoids from "oxidized" I-type or magnetite-series granitoids (Ishihara, 1981, Blevin, 1996). This approach is complicated by the fact that magnetic susceptibility is also a function of the bulk composition (Fe-rich mafic rocks may contain more magnetite than Fe-poor felsic rocks). This complication notwithstanding, magnetic susceptibility in common granitoid rocks ranges across 2 to 3 orders of magnitude and appears to reliably distinguish the main granitoid series (Blevin, 1996). Additional complications can arise from subsolidus transformations that can either diminish (magnetite-destructive alteration – e.g., alteration of magnetite to hematite or pyrite) or enhance (magnetite-forming alteration – e.g., exsolution of Fe-Ti oxides from ferromagnesian minerals) magnetic susceptibility.

Table 6. Summary of characteristics used to infer the fO_2 of plutonic rocks associated with the Hemlo greenstone belt.

Pluton	Fe_3O_4/FeO^a	Magnetic Susceptibility ($\times 10^{-3}$) ^a	Primary Fe-Ti Oxides ^c	Magmatic Sphene ^c	Magmatic Epidote ^c
Black-Pic and Pukaskwa batholiths ^b	0.83 $\pm$.16 (17) 0.54 – 1.08	3.51 $\pm$ 3.82 (46) -0.01 – 15.3	Common, minor magnetite	Common, minor	Common, minor
Dotted Lake batholith	0.94 $\pm$.21 (11) 0.51 – 1.40	2.15 $\pm$ 2.01 (20) -0.02 – 1.40	Rare, trace magnetite	Common, minor	Common, minor
Heron Bay pluton	0.86 $\pm$.17 (33) 0.41 – 1.43	0.45 $\pm$ 0.72 (36) 0.00 – 2.89	Rare, trace magnetite	Ubiquitous, minor	Ubiquitous, minor to abundant
Cedar Lake pluton-Main	0.79 $\pm$.13 (16) 0.50 – 1.06	4.00 $\pm$ 3.94 (29) 0.07 – 15.4	Common, minor magnetite	Ubiquitous, abundant	Common, trace to minor
Cedar Lake pluton-Magnetic	1.03, 1.04 (2)	9.43, 10.9 (2)	Ubiquitous, moderately abundant magnetite	Common, abundant	Erratic, minor
Cedar Creek stock	1.21 $\pm$.17 (5) 1.06 – 1.50	13.3 $\pm$ 1.3 (5) 11.8 – 14.9	Ubiquitous, abundant magnetite	Common, abundant	Common, minor
Musher Lake pluton	0.67 $\pm$ 0.09 (5) 0.57 – 0.78	3.14 $\pm$ 1.32 (5) 1.07 – 4.69	Ubiquitous, minor to trace magnetite	Ubiquitous, minor	Ubiquitous, minor
Gowan Lake pluton	0.78 $\pm$.09 (16) 0.58 – 0.94	13.9 $\pm$ 5.8 (26) 0.21 – 26.5	Ubiquitous, abundant magnetite/ Common, minor titanomagnetite and ilmenite	Common, minor	Common, minor
Fourbay Lake pluton	0.68, 0.92, 0.94, 0.98 (4)	11.5, 19.0, 23.0, 23.0 (4)	Ubiquitous, abundant magnetite/ minor titanomagnetite and ilmenite	Common, minor	Common, trace

^a Whole rock Fe_2O_3/FeO (from XRF/wet chemistry) and magnetic susceptibility are reported as follows: average $\pm$ 1 standard deviation, number of determinations in brackets followed by the range. Individual sample data are listed for the magnetic phase of the Cedar Lake pluton and Fourbay Lake pluton for which limited data is available.

^b Characteristics listed are those of the main foliated to gneissic, tonalitic to granodioritic phases only.

^c All of these minerals have several modes of occurrence but this table refers only to those occurrences that are interpreted to be primary magmatic phases. Each mineral is described in terms of its frequency of occurrence (rare, common, ubiquitous) and characteristic abundance (trace, minor, abundant) in the respective units.

True magnetic susceptibilities were measured with a portable magnetic susceptibility meter (Model- Exploranium KP-9) operated in the 'pin mode'. Measured magnetic susceptibilities have a range in excess of three orders of magnitude (Figure 54) and suggest the following:

- The late plutons associated with the Hemlo greenstone belt (with the exception of the Heron Bay pluton) have susceptibilities ranging from 1×10^{-3} to 30×10^{-3} SI units. These values are typical of those characterizing relatively oxidized I-type granites (c.f., Blevin, 1996).
- The Heron Bay pluton exhibits a large range in magnetic susceptibility, ranging from those characterizing I-type granites to very low susceptibilities more typical of those characterizing S-type granites. This is consistent with the low abundance of magnetite in the Heron Bay pluton. The general mineralogical and geochemical characteristics of the Heron Bay pluton strongly suggest that it is an I-type granite. Magnetite-free I-type granites have also been reported from the Lachlan fold belt although in that case the low magnetite abundance may be related to lower $\text{Fe}_2\text{O}_3/(\text{Fe}_2\text{O}_3+\text{FeO})$ ratio (Whalen and Chappell, 1988). Magnetite-destructive alteration is an unlikely explanation due to the absence of petrographic evidence for such a process and the relatively uniform (with the exception of two samples) $\text{Fe}_2\text{O}_3/(\text{Fe}_2\text{O}_3+\text{FeO})$ ratio that is inconsistent with extensive hematization or sulphidation of magnetite. Relatively low $\text{Fe}_2\text{O}_3^{\text{Total}}$ abundance may have inhibited formation of magnetite although the Cedar Creek and Botham stocks have comparable or lower $\text{Fe}_2\text{O}_3^{\text{Total}}$ abundances and have high susceptibility.
- The Cedar Creek and Botham stocks have high magnetic susceptibilities even though they have relatively low $\text{Fe}_2\text{O}_3^{\text{Total}}$. These units are characterized by relatively high $\text{Fe}_2\text{O}_3/(\text{Fe}_2\text{O}_3+\text{FeO})$ whole rock ratio and the high magnetic susceptibility is most reasonably explained by the magmas being intrinsically highly oxidized. The anomalously magnesium-rich nature of biotite in relation to whole rock Mg # (Figure 46) of these two plutons (as well as the Terrace Bay batholith) may also be a consequence of these magmas being highly oxidized (Czamanske and Wones, 1973).

Several other characteristics are consistent with the interpretation that many of the late plutons associated with the Hemlo greenstone belt were relatively highly oxidized. In addition to the common presence of magnetite, other primary magmatic phases that may be indicative of relatively highly oxidized magmas include sphene and epidote. Wones (1989) has proposed that the assemblage titanite + magnetite + quartz is indicative of relatively high oxygen fugacities (intermediate between fayalite-magnetite-quartz and hematite-magnetite buffers). This mineral assemblage is present in all of the late plutons and is especially common in the Cedar Lake and Musher Lake plutons. The formation of magmatic epidote, which is widely distributed in all of the later plutons, is also thought to be indicative of crystallization under relatively oxidizing conditions (Zen and Hammarstrom, 1984; Schmidt and Thompson, 1996).

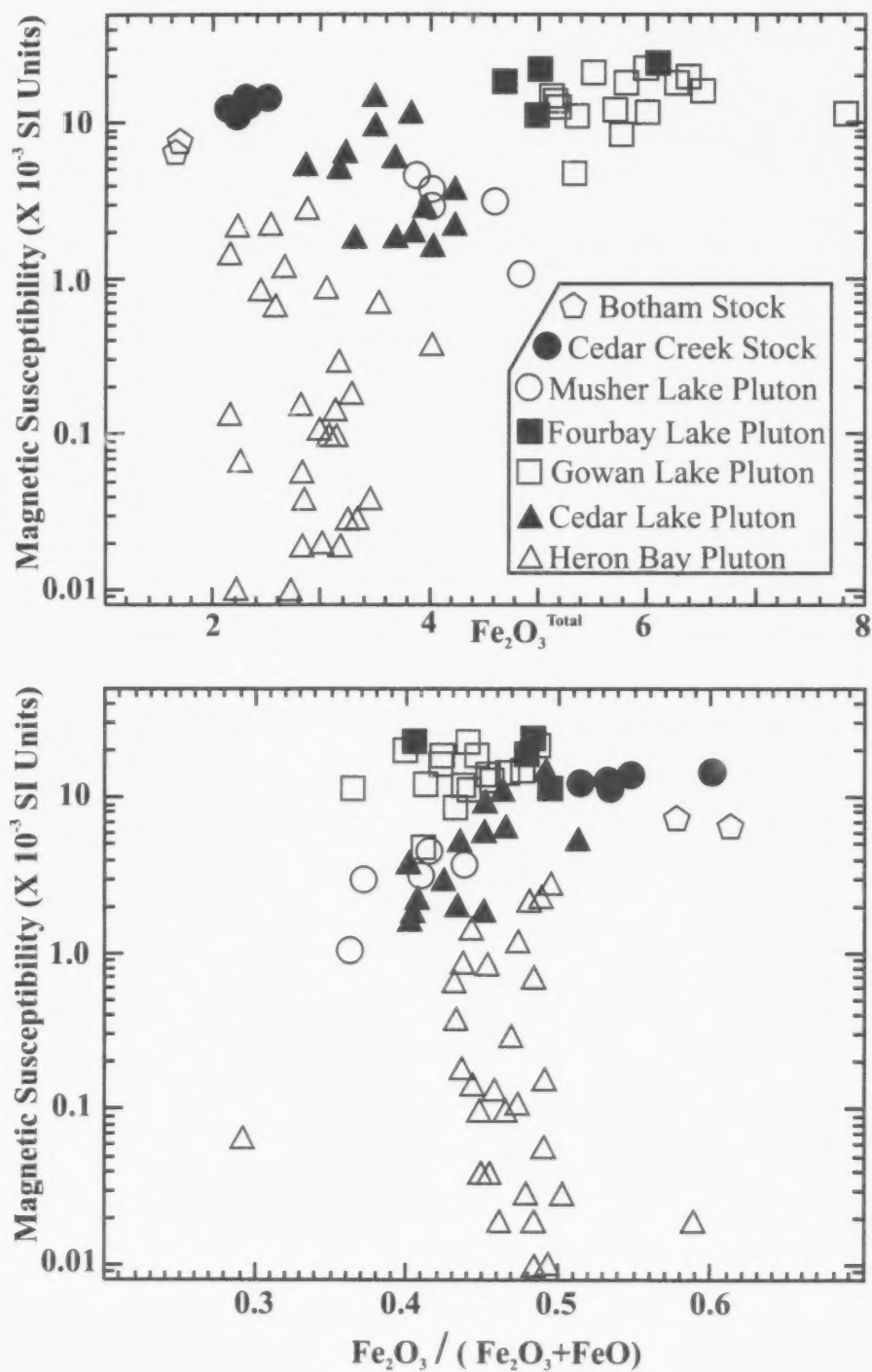


Figure 54. Variation in magnetic susceptibility in late plutons associated with the Hemlo greenstone belt as a function of whole rock $\text{Fe}_2\text{O}_3^{\text{Total}}$ and $\text{Fe}_2\text{O}_3 / (\text{Fe}_2\text{O}_3 + \text{FeO})$.

All of the late plutons associated with the Hemlo greenstone belt are relatively highly oxidized and there is some tendency for the youngest plutons to be the most oxidized. The Heron Bay pluton is anomalous. Although it, like the other late plutons, displays I-type characteristics, the Heron Bay pluton may be the least oxidized and displays an unusually large range in magnetic susceptibility. The reasons for the anomalous redox characteristics of this pluton are not fully understood but it may relate in part to the relatively Fe-poor nature of this unit. It is probable that the late plutons, in general, are characterized by oxygen fugacities at least as oxidizing as the fayalite – magnetite – quartz buffer. Two units (Cedar Creek and Botham stocks) that are closely spatially associated with the Hemlo gold deposit are apparently very highly oxidized. This finding is consistent with the conclusions of a more comprehensive investigation of the oxygen fugacity of the Cedar Creek stock that found evidence suggesting magmatic fO_2 intermediate between the hematite – magnetite and nickel – nickel oxide buffers (Cameron and Carrigan, 1987). It is also noteworthy that the Terrace Bay batholith, occurring in the Terrace Bay – Schreiber greenstone belt, has some characteristics (anomalously Mg-rich biotite, magnetic susceptibility $\sim 12\text{--}15 \times 10^{-3}$ SI units) in common with the Cedar Creek and Botham stocks and is also spatially associated with Au and Cu-Mo mineralization (Marmont, 1984). The possible significance of this relationship is discussed in a subsequent section but it is clear that there is a spatial association between the Hemlo gold deposit and the most highly oxidized plutons intruding the Hemlo greenstone belt.

Secular Evolution of Granitoid Rocks associated with the Hemlo Greenstone Belt

The foregoing discussion has summarized field, petrographic, geochemical and mineral chemical data that constrain the petrogenesis of granitoid plutonism associated with the Hemlo greenstone belt. The characteristics of plutons associated with the Hemlo greenstone belt appear to be a function of the age of the pluton. The changes in these characteristics have been interpreted to reflect changes in pluton petrogenesis. This section summarizes the nature of this secular evolution in granitoid plutonism associated with the Hemlo greenstone belt.

Units considered are restricted to those for which reasonable U-Pb geochronological constraints are available. The oldest units are the types 1 and 2 foliated to gneissic tonalites of the Black-Pic and Pukaskwa batholiths that have U-Pb ages of approximately 2720 Ma. The ages of widespread, diverse, minor phases that are a conspicuous component of these batholiths are well not constrained and are not considered here. The Dotted Lake batholith (~ 2697 Ma) is intermediate in age. A number of other plutons emplaced between 2677 Ma and 2690 Ma are discussed both collectively (when they are referred to as the later plutonic group) and individually. Units comprising the later plutonic group (age estimates in brackets) include the Heron Bay pluton (~ 2690 Ma), Botham stock (~ 2688 Ma), Cedar Lake pluton (~ 2688 Ma), Cedar Creek stock (~ 2684 Ma), Musher Lake pluton (~ 2679 Ma), Gowan Lake pluton (~ 2678 Ma) and Fourbay Lake pluton (~ 2678 Ma). The restricted time interval over which the later plutonic group was emplaced, together with the uncertainty in individual age estimates (discussed in preceding sections) and similarity of some of the ages make it possible that the relative

ages of certain pairings of plutons might be reversed although the general pattern is reasonably well established.

The ages of the tonalitic component of the Black-Pic and Pukaskwa batholiths and the Dotted Lake batholith are comparable to, or older than, many of the supracrustal rocks of the Hemlo greenstone belt which are mostly 2693 Ma to 2698 Ma (Corfu and Muir, 1989a; Davis et al., 1998). The age of the tonalitic component of the Black-Pic and Pukaskwa batholiths is closely comparable to the age of volcanic rocks in the Manitouwadge greenstone belt (Zaleski et al., 1999) and volcanic rocks of comparable age may occur in some of the stratigraphically-low, mafic-dominated assemblages of the Hemlo greenstone belt for which no geochronological data are available. All of the aforementioned batholiths have fabrics that are parallel to the boundaries and internal fabrics of the Hemlo greenstone belt which, together with their comparable ages, suggests that these units and the greenstone belt had similar fabrics superimposed on them and were subsequently folded together. In contrast, plutons of the later plutonic group are massive or have much more weakly developed fabrics that, in some cases, are interpreted to be primary magmatic flowage fabrics. The only exception to this generalization is that the southwestern portion of the Cedar Lake pluton has a notable tectonic deformational fabric (though much less intensely developed than that in the earlier batholiths). The origin of this fabric is not definitively established but it could be pluton induced or be related to late deformational events. The Heron Bay pluton crosscuts the peak metamorphic D_1 deformational fabric in the country rocks (Plate 7) and the Musher Lake pluton contains inclusions of country rock within which the peak metamorphic deformational fabric is folded (Plate 10). Many of the late plutons core regional scale folds but lack deformational fabrics associated with that deformation that are recorded in the country rocks and are consequently interpreted to have been emplaced into the folds as they were developing. The contrasting pressures inferred from Al-in-hornblende geobarometry for the older and younger units of the later plutonic group (~ 4.0 - 4.6 kbars vs ~ 3.1 - 3.6 kbars, respectively) may indicate that regional scale folding was attendant with uplift and erosion that was responsible for decompression.

The major secular changes in the abundances of major rock-forming minerals involve a change from early relatively leucocratic, biotite $\pm$ hornblende tonalitic to granodioritic compositions to later, more melanocratic, hornblende $\pm$ biotite $\pm$ pyroxene granodioritic to quartzmonzodioritic compositions (Figures 3 and 4). The lower abundance of quartz that imparts an overall quartz monzodioritic composition and presence of pyroxene in the main phases of the plutons is restricted to the youngest plutons (Fourbay and Gowan Lake plutons) although minor phases in some of the earliest plutons of the later plutonic group (e.g., quartz monzodioritic and pyroxene-bearing phases of the Cedar Lake pluton and Mg-rich phase of the Heron Bay pluton) share some of these characteristics. A subtle increase in abundance of k-feldspar with decreasing age of plutons is also noteworthy. This trend of increasing k-feldspar with increasing colour index and decreasing quartz abundance is contrary to that expected to result from crystal liquid fractionation. Although more difficult to quantify, the abundance of a range of primary magmatic accessory minerals, including magnetite, epidote and sphene, tends to be greater in plutons younger than 2690 Ma.

The geochemical characteristics of the later plutonic group plutons are, as a whole, distinctive with respect to the earlier foliated to gneissic tonalite component of the belt-bounding batholiths and the Dotted Lake suite. The later plutonic group tends to be more mafic and distinctly metaluminous reflecting the predominance of hornblende over biotite. The later plutonic group is also characterized by lower SiO_2 and higher $\text{Fe}_2\text{O}_3^{\text{T}}$, MgO , $\text{Mg\#}$, CaO , P_2O_5 , TiO_2 , Y, Zr, Nb, Th, U, Ta, V, Ni, Cr, Ce and Yb. Selected geochemical parameters are tabulated in table 7 and plotted as a function of the age of units in Figure 55. Units plotted (number of samples in brackets) include the type 1 (4) and type 2 (10) tonalitic rocks of the belt-bounding batholiths, Dotted Lake batholith (11), Heron Bay Pluton excluding high-Mg samples (30), main phase of Cedar Lake pluton (14), Cedar Creek stock (5), Musher Lake pluton (5), Gowan Lake pluton (16) and Fourbay Lake pluton (4). Note that the ages of the belt-bounding tonalitic rocks and Musher Lake and Fourbay Lake plutons is shifted slightly in Figure 55 in order that symbols not interfere. The later plutonic group also displays a general tendency to very weak negative Eu anomalies as opposed to a tendency to weak positive Eu anomalies in the older suites. As discussed in the preceding section, the younger rocks may also have comparable to slightly less radiogenic Nd (Figure 53).

Within the later plutonic group there also appears to be a general secular evolution that broadly continues that described above but diverges in several respects. The restricted time interval over which this group was emplaced (~13 Ma) and difficulties (inheritance, overgrowths) in interpreting the U-Pb zircon age of the Heron Bay pluton complicate this interpretation. Nevertheless, there appears to be a general mineralogical and geochemical progression from earlier (Heron Bay ~2690 Ma) through intermediate (Cedar Lake ~2688 Ma; Cedar Creek ~2684 Ma) to later (Musher Lake, Gowan Lake and Fourbay Lake ~2678 Ma) plutons that parallels many of the trends discussed above. In particular, the youngest plutons are decidedly more metaluminous with predominant hornblende accompanied by clinopyroxene and enriched HFSE and REE. Although the LREE are most abundant in the youngest plutons, the greater abundance of HREE reverses the secular trend of increasing REE fractionation apparent from comparing the earlier gneissic tonalite and Dotted Lake suites with the earlier plutons of the later plutonic group.

Variation in the whole rock geochemical characteristics of plutons of different ages is apparent in many plots of compatible versus incompatible elements. An example of this relationship is apparent in a plot of MgO versus K_2O (Figure 56). Typical crystal-liquid fractionation processes result in such element pairs being negatively correlated as compatible elements (e.g., MgO) are concentrated in residual or cumulate mineral phases and incompatible elements (e.g., K_2O) are concentrated in the melt. Many of the plutons have limited internal compositional variation but such an inverse correlation is apparent for some of the individual plutons (Figure 56). The trend of inter-unit variation is the reverse of that expected from crystal-liquid fractionation processes with MgO and K_2O being positively correlated. This suggests that the overall trend cannot be due to differential fractionation of comparable magmas or different degrees of melting of similar source materials. Arguments advanced above and in the pluton specific discussion limit

Table 7. Range and average composition of plutons of known age associated with the Hemlo greenstone belt

	Belt-Bounding Batholiths ~2720 Ma										Dotted Lake Bath 2697±1 Ma										Heron Bay Pluton- Main Phase ~2690 Ma													
	Type 1 (4 analyses)					Type 2 (6 analyses)					Main Phase (11 analyses)					Main Phase (30 analyses)					Mg-rich Phase (4 analyses)					Avg/Std Dev								
	Min	Max	Avg	Std Dev		Min	Max	Avg	Std Dev		Min	Max	Avg	Std Dev		Min	Max	Avg	Std Dev		Min	Max	Avg	Std Dev		Min	Max	Avg	Std Dev		Min	Max	Avg	Std Dev
SiO ₂	69.58	70.91	70.37	0.65	67.26	71.78	69.76	1.63			69.18	74.09	71.75	1.41		64.44	68.75	66.91	1.28		61.53	63.62	62.71	0.89		61.53	63.62	62.71	0.89					
Al ₂ O ₃	15.30	16.02	15.78	0.34	14.71	15.98	15.36	0.49			14.55	15.85	15.07	0.38		15.45	16.78	15.94	0.29		15.46	15.80	15.61	0.14		15.46	15.80	15.61	0.14					
MnO	<0.01	<0.01	<0.01		0.02	0.04	0.03	0.01			0.01	0.03	0.02	0.01		0.02	0.06	0.03	0.01		0.07	0.08	0.08	0.01		0.07	0.08	0.08	0.01					
FeO	0.69	0.89	0.79	0.09	1.10	1.79	1.37	0.26			0.37	1.07	0.77	0.26		1.07	2.15	1.44	0.24		2.35	2.89	2.63	0.27		2.35	2.89	2.63	0.27					
Fe ₂ O ₃	0.56	1.05	0.71	0.23	0.60	1.45	1.11	0.30			0.42	1.03	0.69	0.21		0.61	1.70	1.27	0.24		1.56	2.10	1.75	0.24		1.56	2.10	1.75	0.24					
MgO	0.42	0.62	0.52	0.08	0.56	1.02	0.78	0.16			0.26	0.97	0.53	0.23		0.85	1.78	1.22	0.26		2.78	3.23	2.93	0.20		2.78	3.23	2.93	0.20					
CaO	2.24	2.83	2.47	0.27	2.45	3.53	2.91	0.46			1.28	2.96	2.05	0.49		2.40	3.76	3.09	0.30		3.84	4.81	4.24	0.43		3.84	4.81	4.24	0.43					
Na ₂ O	5.43	5.99	5.78	0.25	4.85	5.95	5.31	0.39			5.08	6.10	5.55	0.36		5.09	5.84	5.42	0.19		4.61	5.10	4.94	0.23		4.61	5.10	4.94	0.23					
K ₂ O	0.90	1.79	1.39	0.37	0.92	1.76	1.21	0.30			1.07	2.07	1.67	0.39		1.39	2.57	2.16	0.27		1.62	2.49	2.12	0.36		1.62	2.49	2.12	0.36					
TiO ₂	0.21	0.31	0.24	0.05	0.21	0.38	0.31	0.08			0.11	0.24	0.17	0.05		0.27	0.46	0.36	0.05		0.39	0.51	0.44	0.05		0.39	0.51	0.44	0.05					
P ₂ O ₅	0.02	0.05	0.03	0.02	0.02	0.07	0.04	0.02			0.01	0.02	0.02	0.00		0.02	0.09	0.07	0.02		0.08	0.11	0.10	0.01		0.08	0.11	0.10	0.01					
LOI	0.40	0.60	0.48	0.09	0.40	0.74	0.51	0.12			0.38	1.06	0.68	0.25		0.38	1.17	0.67	0.19		0.77	1.30	1.01	0.23		0.77	1.30	1.01	0.23					
Mg#	36	43	39	3	32	44	37	6			36	47	40	3		42	49	45	2		54	57	55	1		54	57	55	1					
A/CNK	1.01	1.03	1.02	0.01	0.93	1.05	1.00	0.04			1.01	1.06	1.03	0.02		0.88	0.99	0.94	0.02		0.84	0.87	0.86	0.02		0.84	0.87	0.86	0.02					
Li	19	26	22	3	18	36	25	7			13	60	32	13		9	32	20	6		12	21	16	4		12	21	16	4					
Cs	0.45	2.01	1.11	0.66	0.71	2.76	1.54	0.87			0.28	2.71	1.38	0.68		0.51	3.54	1.72	0.85		0.64	2.52	1.22	0.88		0.64	2.52	1.22	0.88					
Rb	24	57	38	14	29	50	42	8			29	58	45	10		27	81	59	11		43	78	55	16		43	78	55	16					
Sr	885	1048	948	75	333	1065	528	274			291	753	507	160		781	1232	1027	103		885	1132	999	121		885	1132	999	121					
Ba	527	794	666	109	338	727	477	140			385	908	595	189		872	1268	1013	104		753	1086	977	152		753	1086	977	152					
Nb	1.0	1.5	1.1	0.2	2.0	7.0	3.7	2.0			1.4	2.6	2.0	0.5		1.9	4.2	3.1	0.6		3.3	4.4	3.7	0.5		3.3	4.4	3.7	0.5					
Zr	83	111	99	13	75	151	112	29			59	86	73	10		84	135	108	11		103	112	107	4		103	112	107	4					
Ta	0.05	0.09	0.08	0.02	0.16	0.41	0.26	0.11			0.08	0.32	0.18	0.08		0.11	0.30	0.20	0.05		0.21	0.24	0.22	0.01		0.21	0.24	0.22	0.01					
Th	2.08	3.25	2.67	0.49	1.09	3.98	2.50	1.14			0.60	1.34	0.96	0.24		1.52	4.08	2.57	0.51		2.55	3.57	3.02	0.42		2.55	3.57	3.02	0.42					
U	0.12	0.80	0.34	0.31	0.27	0.75	0.53	0.19			0.22	0.43	0.33	0.07		0.45	1.23	0.64	0.16		0.55	0.92	0.70	0.17		0.55	0.92	0.70	0.17					
Sc	1	1	1	0	2	4	3	1			1	4	2	1		2	40	9	11		9	11	10	1		9	11	10	1					
V	17	23	20	3	21	42	32	9			8	28	18	7		34	69	48	9		74	96	82	10		74	96	82	10					
Cr	12	14	13	1	14	17	16	1			10	20	14	3		13	49	30	12		107	132	118	11		107	132	118	11					
Ni	8	8	8	0	5	12	8	3			5	17	9	4		8	21	13	4		30	44	38	6		30	44	38	6					
Co	<5	<5	<5		6	6	6	0			<5	<5	<5			5	9	7	1		10	17	12	3		10	17	12	3					
Cu	13	13	13	0	9	25	18	8			7	8	7	1		5	16	10	3		10	20	15	5		10	20	15	5					
Zn	42	66	52	10	41	86	66	16			28	49	39	6		65	98	81	7		76	88	81	6		76	88	81	6					
Pb	8	11	9	2	7	17	11	4			7	14	10	3		12	21	17	3		14	15	14	1		14	15	14	1					
Y	1.2	1.8	1.5	0.2	3.0	5.9	3.8	1.1			2.6	5.2	3.8	0.9		3.0	7.2	4.3	1.0		8.3	9.6	8.7	0.6		8.3	9.6	8.7	0.6					
La	9.6	23	17	5.6	8.7	29	18	8.3			4.6	9.1	6.6	1.4		9.7	24	17	3.1		18	25	20	3		18	25	20	3					
Ce	21	46	34	10	18	53	35	15			10	18	14	3		21	49	37	6		40	50	43	5		40	50	43	5					
Yb	0.09	0.11	0.10	0.01	0.25	0.42	0.31	0.06			0.17	0.47	0.30	0.10		0.20	0.59	0.33	0.08		0.78	0.90	0.81	0.06		0.78	0.90	0.81	0.06					
Eu/Eu*	1.04	1.38	1.24	0.16	0.92	1.29	1.11	0.15			0.91	1.43	1.20	0.14		0.96	1.22	1.04	0.07		0.92	0.99	0.95	0.03		0.92	0.99	0.95	0.03					
Ce _N /Yb _N	65	116	92	21	17	52	32	13			7	22	14	5		18	49	32	7		14	15	15	1		14	15	15	1					

Table 7 (cont.). Range and average composition of plutons of known age associated with the Hemlo greenstone belt

Botham Stock ~2688 Ma										Cedar Lake Pluton ~2688 Ma														
Med Grained Phase (2 analyses)					Main Phase (14 analyses)					Px-bearing Phase(2 analyses)					Magnetic Phase (2 analyses)					Diorite (6 analyses)				
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
SiO ₂	69.40	70.02	69.71	0.44	62.39	66.86	64.38	1.30	61.83	64.05	62.94	1.57	65.73	67.27	66.50	1.09	50.68	60.80	57.30	3.90				
Al ₂ O ₃	15.32	15.55	15.44	0.16	15.70	16.96	16.25	0.37	16.80	17.14	16.97	0.24	16.59	16.63	16.61	0.03	14.38	16.72	15.04	0.88				
MnO	<0.1	0.01	0.01		0.03	0.05	0.04	0.01	0.03	0.06	0.05	0.02	0.02	0.02	0.02	0.00	0.08	0.20	0.13	0.04				
FeO	0.61	0.68	0.65	0.05	1.32	2.37	1.92	0.30	1.54	2.22	1.88	0.48	1.30	1.39	1.35	0.06	2.58	6.57	4.30	1.34				
Fe ₂ O ₃	0.93	0.97	0.95	0.03	1.25	1.67	1.51	0.13	1.11	1.34	1.23	0.16	1.34	1.45	1.39	0.08	1.55	4.21	2.63	0.93				
MgO	0.58	0.61	0.60	0.02	1.45	2.04	1.72	0.19	1.81	2.32	2.07	0.36	0.87	0.94	0.91	0.05	3.46	5.98	4.48	0.90				
CaO	1.74	2.12	1.93	0.27	2.58	4.01	3.42	0.38	2.65	2.85	2.75	0.14	2.86	3.06	2.96	0.14	4.68	7.63	5.90	1.02				
Na ₂ O	5.70	6.12	5.91	0.30	5.22	5.61	5.43	0.13	6.23	8.09	7.16	1.32	5.68	5.77	5.73	0.06	4.08	4.90	4.57	0.32				
K ₂ O	2.30	2.38	2.34	0.06	2.05	2.77	2.49	0.24	0.71	0.88	0.80	0.12	2.46	2.60	2.53	0.10	0.92	4.38	2.37	1.24				
TiO ₂	0.24	0.25	0.25	0.01	0.38	0.58	0.49	0.05	0.48	0.54	0.51	0.04	0.42	0.49	0.46	0.05	0.55	0.90	0.70	0.14				
P ₂ O ₅	0.02	0.05	0.04	0.02	0.12	0.20	0.16	0.03	0.16	0.18	0.17	0.01	0.10	0.12	0.11	0.01	0.19	0.36	0.28	0.06				
LOI	0.58	0.83	0.71	0.18	0.41	0.92	0.66	0.16	1.62	1.69	1.66	0.05	0.40	0.44	0.42	0.03	0.39	0.87	0.68	0.17				
Mg#	41	42	41	0	45	51	48	1	54	56	55	2	38	38	38	0	45	66	55	7				
A/CNK	0.95	1.01	0.98	0.05	0.88	0.96	0.91	0.02	0.88	1.06	0.97	0.13	0.93	0.97	0.95	0.03	0.65	0.80	0.72	0.05				
Li	16	23	20	5	10	29	20	6	9	19	14	7	36	39	38	2	16	35	23	7				
Cs	2.73	3.14	2.94	0.29	0.76	3.56	1.74	0.87	0.28	0.63	0.46	0.25	2.02	4.44	3.23	1.71	0.72	2.72	1.48	0.75				
Rb	67	67	67	0	41	70	58	8	23	37	30	10	72	79	76	5	27	73	48	17				
Sr	1125	1200	1162	53	1167	1593	1328	122	844	1007	925	116	1087	1131	1109	31	859	1302	1028	160				
Ba	951	1013	982	44	1044	1480	1265	127	396	639	518	172	1001	1023	1012	16	431	1983	974	565				
Nb	1.6	1.8	1.7	0.1	4.2	6.1	5.0	0.6	4.6	7.3	5.9	2.0	4.7	5.4	5.0	0.5	4.9	14.8	8.2	3.6				
Zr	107	117	112	7	125	170	151	12	153	226	190	52	151	151	151	0	133	187	157	18				
Ta	0.11	0.13	0.12	0.01	0.23	0.42	0.30	0.06	0.24	0.50	0.37	0.18	0.26	0.31	0.29	0.04	0.31	1.10	0.52	0.30				
Th	3.15	3.34	3.25	0.13	4.06	7.18	5.33	0.95	6.78	7.04	6.91	0.18	4.25	4.45	4.35	0.14	3.12	11.00	5.84	3.11				
U	0.88	1.02	0.95	0.10	0.55	1.27	0.81	0.24	0.75	1.11	0.93	0.25	1.06	1.12	1.09	0.04	0.60	1.80	1.11	0.43				
Sc	2	10	6	6	3	6	5	1	5	5	5	0	2	3	2	0	8	18	13	3				
V	27	28	28	1	47	69	60	7	55	58	56	2	43	47	45	3	78	184	126	37				
Cr	13	14	14	1	22	39	33	5	29	34	32	4	10	10	10	0	15	271	149	86				
Ni	6	6	6	0	13	27	21	4	21	25	23	3	7	7	7	0	16	122	67	41				
Co	<5	<5	<5		6	11	9	2	8	12	10	2	6	6	6	0	16	31	22	5				
Cu	<5	<5	<5		5	12	9	2	26	235	131	148	8	8	8	0	20	57	38	18				
Zn	80	82	81	1	65	96	87	9	47	77	62	21	87	88	88	1	83	241	145	55				
Pb	21	22	22	1	11	18	16	2	7	7	7	0	17	19	18	1	12	21	15	3				
Y	20	29	24	0.6	50	113	86	17	89	117	103	20	50	59	55	0.6	11.6	24.2	16.5	4.3				
La	19	22	20	2	34	56	45	7	49	69	59	14	33	37	35	3	29	86	51	25				
Ce	40	44	42	3	74	114	93	13	109	137	123	20	70	78	74	6	70	182	111	53				
Yb	0.17	0.19	0.18	0.01	0.43	0.90	0.72	0.13	0.68	0.93	0.81	0.18	0.30	0.34	0.32	0.03	0.97	2.46	1.56	0.55				
Fu/Eu*	0.96	1.12	1.04	0.11	0.85	0.96	0.89	0.03	0.87	0.87	0.87	0.01	0.90	0.90	0.90	0.00	0.76	0.94	0.85	0.06				
ε _{Ni} /Yb _N	65	66	66	1	32	49	37	5	64	126	95	43	64	65	65	1	8	45	22	14				

Table 7 (cont.). Range and average composition of plutons of known age associated with the Hemlo greenstone belt

	Cedar Creek Stock 2684 ^{±3} Ma					Musher Lake Pluton -2679 ±2Ma					Gowan Lake Pluton - 2678 ± 2 Ma					Fourbay Lake Pluton-2678 ±1 Ma				
	Main Phase (5 analyses)			Avg/Std Dev	Main Phase (16 analyses)			Avg/Std Dev	Mafic Enclaves (3 analyses)			Avg/Std Dev	Main Phase (4 analyses)			Avg/Std Dev				
	Min	Max			Min	Max			Min	Max			Min	Max						
SiO ₂	67.24	69.27	68.50	0.77	61.58	64.78	63.07	1.14	54.69	62.70	60.01	2.06	51.80	58.98	55.38	3.59	60.00	62.75	61.74	1.20
Al ₂ O ₃	15.43	15.81	15.68	0.15	15.87	16.81	16.28	0.38	15.31	17.72	16.16	0.59	12.32	13.68	13.08	0.69	15.76	16.47	15.95	0.35
MnO	0.01	0.02	0.02	0.00	0.04	0.06	0.05	0.01	0.08	0.13	0.09	0.01	0.15	0.19	0.17	0.02	0.08	0.10	0.09	0.01
FeO	0.97	1.03	0.99	0.02	2.13	2.89	2.41	0.32	2.53	4.64	3.10	0.53	3.68	5.20	4.64	0.84	2.31	3.38	2.64	0.50
Fe ₂ O ₃	1.05	1.45	1.20	0.15	1.40	1.76	1.59	0.14	2.06	2.67	2.37	0.17	2.08	2.71	2.44	0.32	2.13	2.35	2.27	0.10
MgO	0.70	0.79	0.74	0.03	1.79	2.26	2.02	0.18	2.15	4.17	2.77	0.49	4.87	10.13	6.93	2.81	1.92	2.66	2.15	0.35
CaO	2.24	2.47	2.39	0.11	2.99	3.92	3.46	0.33	3.52	5.46	4.22	0.57	5.08	8.23	6.40	1.64	3.30	4.46	3.68	0.54
Na ₂ O	5.65	5.80	5.73	0.06	4.42	5.15	4.75	0.27	4.17	5.42	4.72	0.34	2.27	2.63	2.48	0.19	4.51	4.93	4.73	0.17
K ₂ O	2.12	2.59	2.37	0.20	2.38	3.64	2.86	0.56	1.56	3.92	3.30	0.58	3.12	6.07	5.04	1.66	3.18	4.16	3.75	0.45
TiO ₂	0.35	0.42	0.38	0.03	0.49	0.62	0.54	0.05	0.50	0.77	0.57	0.07	0.50	0.62	0.55	0.06	0.50	0.61	0.53	0.05
P ₂ O ₅	0.06	0.11	0.08	0.02	0.10	0.17	0.15	0.03	0.18	0.32	0.25	0.04	0.22	0.34	0.28	0.06	0.25	0.26	0.26	0.00
LOI	0.46	0.99	0.63	0.21	0.63	1.62	1.07	0.43	0.44	1.65	0.85	0.36	0.53	0.91	0.77	0.21	0.35	0.57	0.44	0.10
Mg#	38	41	39	1	47	50	48	1	45	51	48	2	59	70	63	6	44	47	45	1
A/CNK	0.94	0.98	0.96	0.02	0.92	1.00	0.95	0.03	0.80	0.89	0.85	0.02	0.54	0.69	0.62	0.07	0.85	0.87	0.86	0.01
Li	23	32	27	4	18	26	23	4	14	31	22	5	12	34	20	12	21	33	25	6
Co	0.88	1.09	1.01	0.09	0.47	2.10	1.64	0.66	0.69	4.14	2.16	0.93	1.06	1.56	1.32	0.25	2.01	3.79	3.13	0.77
Rb	55	66	59	5	37	95	69	25	46	133	90	20	75	127	98	27	79	109	98	14
Sr	1000	1226	1093	83	788	1084	950	130	767	1255	1003	158	679	725	707	25	941	1048	991	44
Ba	782	1014	898	92	831	1889	1227	402	1008	1729	1328	170	1282	2676	1843	736	1321	1377	1353	24
Nb	3.5	4.7	3.9	0.5	4.6	7.0	5.6	0.9	7.1	10.0	8.3	0.7	8.2	22.1	13.5	7.5	8.2	11.3	9.5	1.3
Zr	121	138	129	7	130	151	140	9	151	210	178	17	137	147	141	5	170	192	182	9
Ta	0.25	0.28	0.26	0.01	0.27	0.49	0.35	0.09	0.35	0.73	0.52	0.12	0.32	0.89	0.65	0.29	0.58	1.77	0.97	0.54
Th	3.15	4.37	3.51	0.49	3.15	4.89	4.08	0.65	2.62	11.18	6.73	2.13	1.36	8.48	4.38	3.68	5.53	11.99	8.30	2.69
U	0.64	0.84	0.70	0.08	0.52	0.92	0.76	0.17	0.72	1.56	1.08	0.29	0.45	1.95	1.05	0.79	0.68	2.27	1.37	0.72
Sc	2	2	2	0	6	60	18	24	8	100	21	28	12	16	15	2	7	11	9	2
V	31	38	34	3	68	86	76	8	76	134	93	15	87	123	107	18	70	101	80	14
Cr	12	17	14	2	33	37	35	2	21	76	43	18	213	653	419	221	19	22	21	1
Ni	6	8	7	1	17	22	19	2	11	26	17	4	44	107	73	32	10	12	11	1
Co	<5	<5	<5		7	13	10	2	9	17	12	2	18	33	25	8	8	12	10	2
Cu	<5	<5	<5		7	14	9	3	9	20	15	3	10	10	10	0	5	16	11	6
Zn	72	96	80	9	71	91	82	9	70	107	84	9	93	113	101	11	72	84	78	5
Pb	13	15	14	1	7	18	12	4	10	25	17	4	9	18	14	5	20	30	24	5
Y	4.1	4.5	4.3	0.2	8.0	12.2	10.6	1.7	15.2	24.2	18.1	2.3	18.2	23.4	20.2	2.9	14.9	17.8	16.7	1.3
La	24	35	27	5	25	36	33	5	34	56	44	7	25	69	41	24	46	58	53	6
Ce	50	73	57	9	55	79	71	10	79	123	95	14	72	159	104	48	101	136	119	15
Yb	0.24	0.28	0.27	0.02	0.69	0.97	0.88	0.11	1.48	2.16	1.67	0.15	1.70	2.34	2.01	0.32	1.44	1.76	1.66	0.15
Eu/Eu*	0.95	1.03	0.99	0.03	0.74	0.99	0.89	0.09	0.85	0.97	0.88	0.03	0.86	0.87	0.87	0.01	0.85	0.91	0.87	0.02
Ce _N /Yb _N	51	84	60	14	19	25	22	2	12	58	19	11	9	72	31	36	21	56	42	16

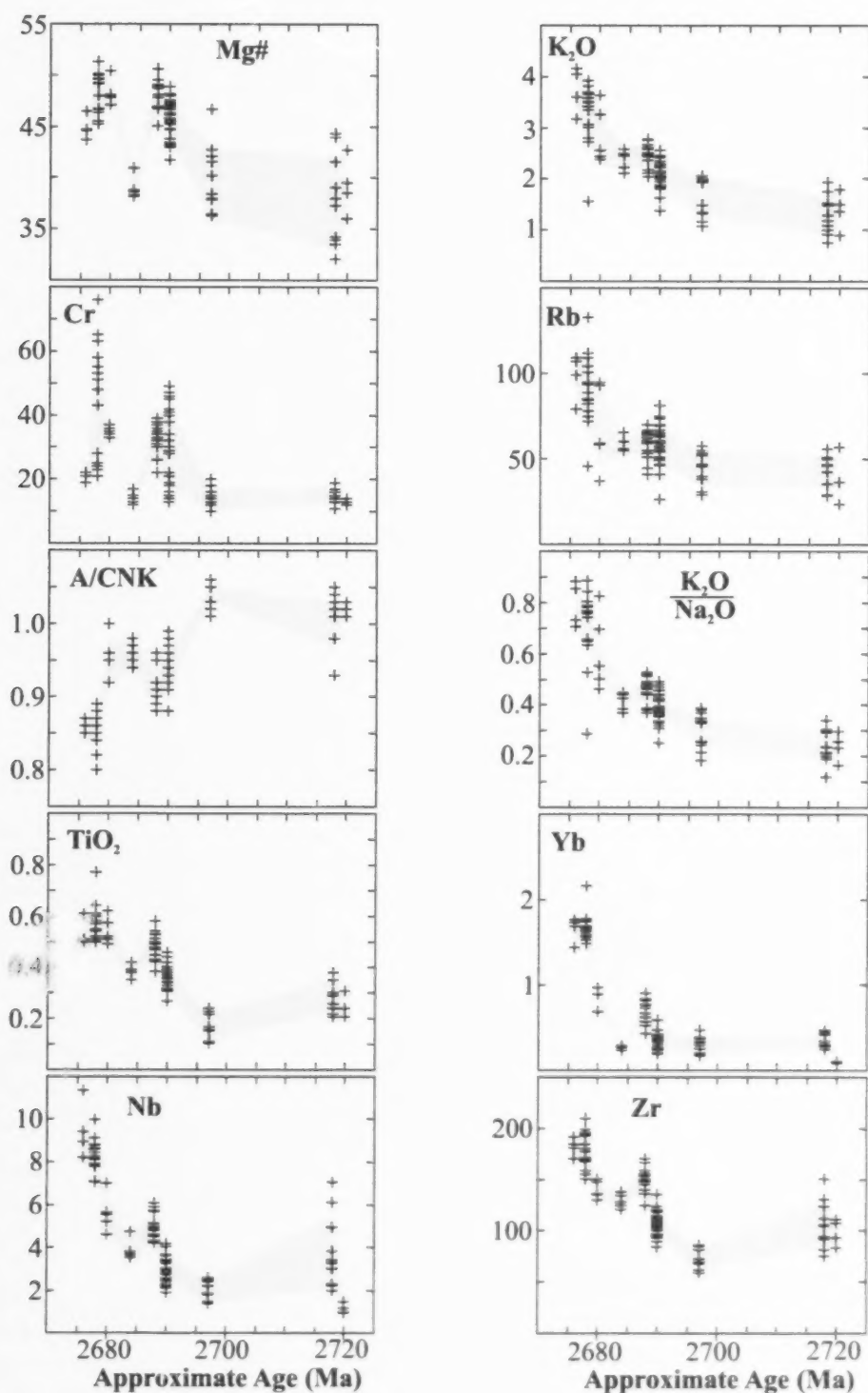


Figure 55. Secular evolution of selected geochemical parameters for plutons associated with the Hemlo greenstone belt. Units plotted are, from right to left, belt-bounding type 1 tonalites, belt-bounding type 2 tonalites, Dotted Lake batholith, Heron Bay Pluton, Cedar Lake pluton, Cedar Creek stock, Musher Lake pluton, Gowan Lake pluton and Fourbay Lake pluton. The shaded areas are defined by the mean $\pm$ 1 standard deviation for each of these units. Note that some of the ages are shifted slightly to preserve clarity as discussed in the text.

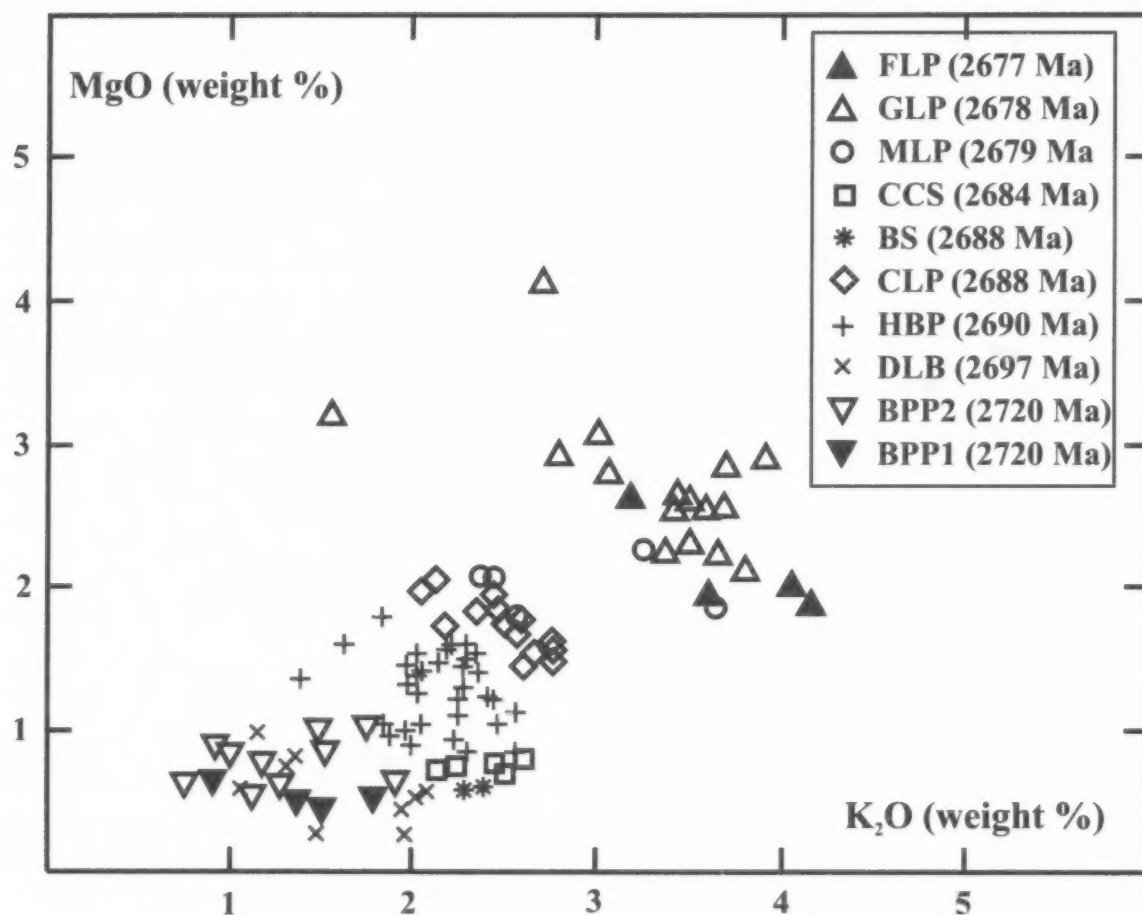


Figure 56. MgO versus K₂O whole rock abundances (weight %) for major phases of plutons associated with the Hemlo greenstone belt. Abbreviations for units illustrated on the diagram are as follows; BPP1- Black-Pic and Pukaskwa batholiths type 1 tonalites, BPP2 - Black-Pic and Pukaskwa batholiths type 2 tonalites, DLB - Dotted Lake batholith, HBP - Heron Bay pluton, CLP - Cedar Lake pluton, BS - Botham Stock, CCS - Cedar Creek Stock, MLP - Musher Lake pluton, GLP - Gowan Lake pluton, FLP - Fourbay Lake pluton. The approximate age of these units is indicated in the diagram.

the role of crustal contamination as an explanation for the elevated K₂O in MgO-rich units. As discussed below, these patterns can be reconciled with the younger phases being derived from a more Mg-rich (ultramafic) source that was metasomatically enriched in incompatible elements prior to melting.

Assessment of the variation in mineral chemistry with the age of the plutons is hampered by the more limited numbers of samples characterized which makes it difficult to assess the nature of intra-pluton variation. Variation in mineral composition is influenced by a wide range of factors including bulk composition, intrinsic properties of the magma and late magmatic to subsolidus re-equilibration of mineral phases. Although the bulk composition of many of the plutons is distinctive and reasonably well constrained, the compositions of mineral phases does not, in general, vary as systematically as do the whole rock compositions.

The An content of plagioclase exhibits a positive correlation with whole rock CaO content and tends to increase with decreasing age of units although in some cases (e.g., sample 7175 from Gowan Lake pluton) subsolidus alteration has resulted in extreme deviation from this correlation. Composition of microcline is relatively consistent and no distinctive trends have been recognized. Ferromagnesian minerals display a general trend to becoming more Mg-rich in the younger plutons within more Mg-rich whole rock composition although for several of the plutons (e.g., Botham and Cedar Creek stocks and possibly the undated Ogilvie Island pluton and Terrace Bay batholith) their Mg-rich character may be strongly influenced by their highly oxidized character.

The overall change in the mineralogy and whole rock geochemistry point to changes in the petrogenesis and tectonic setting of granitoid plutonism associated with the Hemlo greenstone belt. The petrogenesis of specific plutons has been discussed in preceding sections and the general characteristics of the change in granitoid petrogenesis are discussed below.

The earlier plutonic units including the foliated to gneissic component of the Black-Pic and Pukaskwa batholiths and the Dotted Lake batholith are characterized by relatively high SiO₂ and Na₂O/K₂O and relatively lower K₂O, Mg#, Rb, Sr, Ba, Zr, Y, Ni, Cr and V. These rocks exhibit moderately fractionated REE patterns with depleted HREE and negligible or weak positive Eu anomalies. These characteristics are typical in most respects of Superior Province TTG suites that have been interpreted be products of melting of tholeiitic basalt at lower crustal or upper mantle depths (e.g., Arth and Hanson, 1972, 1975; Beakhouse and McNutt, 1991). This model accounts for the general major element characteristics (Helz, 1976) including the distinctive low LILE abundances. The depth constraint arises from the need to stabilize garnet (or less favorably hornblende) in the residue to account for the characteristic HREE and Y depletion observed in these rocks. Basaltic crust source material could be introduced at depths appropriate for the requisite metamorphic mineral assemblages and partial melting conditions by several mechanisms. Basaltic crust could be formed at the base of the crust by magma underplating, transported to the base of the crust by large scale accretion processes or by subduction of oceanic crust. Tonalitic magmas are areally extensive and, assuming

surface exposure is representative of much of the upper crust, voluminous in the Hemlo greenstone belt area as well as more regionally (Beakhouse et al., 1989). The parameters for partial melting of tholeiitic basalt giving rise to tonalitic melts require that the volume of source basalt be 5 to 10 times that of the derived tonalite. These factors impose a further constraint that the process be highly efficient in order to both cycle very significant volumes of basaltic crust to appropriate depths and dispose of the residue from partial melting and on this basis, the subduction of basaltic oceanic crust is the preferred interpretation.

The later plutonic group displays considerable diversity, some of which can be broadly correlated with the age of the units. The mineralogical and geochemical characteristics of youngest units within the later plutonic group (Gowan Lake pluton, Fourbay Lake pluton, Melgund stock?) display an apparent dichotomy. On one hand, their mafic, quartz-poor and low SiO_2 character and relatively high CaO , MgO , TiO_2 and P_2O_5 suggest that these are relatively primitive magmas yet they also display abundant, highly fractionated REE and abundant LILE. They also have high abundances of a wide range of HFSE and, in the case of the Melgund stock, relatively high Ni, Cr and Mg#. Shirey and Hanson (1984) identified units with comparable characteristics, which they termed sanukitoids, and interpreted them to be products of partial melting of metasomatized mantle. Similar rocks and interpretations were subsequently identified by others (Stern et al., 1989; Sutcliffe et al., 1990) and a similar origin is favored for certain of the units at Hemlo.

The older units within the later plutonic group (e.g., Heron Bay pluton, Cedar Lake pluton) have compositions intermediate between those of the earlier suites interpreted to be products of melting of tholeiitic basalt and the youngest plutons that may be a product of melting of metasomatized mantle. Evidence for a mingled more mafic dioritic phase with the Cedar Lake pluton granodiorite phase suggests that a mantle-derived magmatic component at least coexisted with the Cedar Lake pluton. The Mg-rich phase of the Heron Bay pluton also has affinities with the younger mantle-derived plutons suggesting that this type of magmatism was at least a component of the earliest stages of the later plutonic group. It is possible that the intermediate compositions of the Cedar Lake and Heron Bay plutons represent end members of either of the processes described in preceding paragraphs or that they represent a mixing of these two components. In either case, the earliest components of the later plutonic group mark a turning point or transition in the magmatic history of the Hemlo greenstone belt area from a dominantly basalt (slab) derived component to a metasomatized mantle-derived magmatic component. The cessation of the slab derived magmatic component may indicate that the subduction process was terminated or migrated to another site.

Summary

The following observations and conclusions are relevant to understanding the relationship between intermediate and felsic intrusive rocks and the greenstone belt as well as the setting of the Hemlo gold deposit:

The earliest intrusive rocks are pre- or synvolcanic and are interpreted to have been deformed along with the greenstone belt.

The later plutonic group plutons post-date the imposition of well-developed fabrics on the greenstone belt and earlier intrusive rocks and were emplaced during the regional scale folding (D_2) of the greenstone belt, earlier intrusive rocks and D_1 fabric.

The Moose Lake porphyry is interpreted to be an endogenous felsic dome with the massive portion (flow or high level subvolcanic intrusion) corresponding approximately to the position of the Hemlo gold deposit. Consequently, unless this unit unconformably overlies others in the greenstone belt, it has undergone the same sequence of deformational events as other supracrustal rocks in the greenstone belt.

The geological history of the area progressed rapidly from 1) early magmatic activity which gave rise to the greenstone belt and early intrusive rocks, 2) imposition D_1 fabrics and 3) folding of the D_1 fabric accompanied by the emplacement of a variety of late intrusive rocks.

Most of the later plutonic group plutons are medium to coarse grained and either equigranular or coarsely porphyritic/microcline megacrystic. The Heron Bay pluton is anomalous with both medium grained and finer grained, plagioclase subporphyritic varieties with the latter concentrated in the eastern portion of the pluton.

Intermediate to felsic dikes are a widespread component of the Hemlo greenstone belt but their abundance and diversity in the Hemlo deposit area appears to be unique. These dikes may indicate this area underwent a brief, localized, extensional tectonic phase synchronous with the later magmatic phase within an area and region dominated by compressional tectonics.

Intermediate to felsic intrusive rocks display a secular compositional evolution from earlier, more leucocratic, biotite $\pm$ hornblende tonalites and granodiorites with a strong TTG, slab-melting geochemical signature to later, more mafic hornblende $\pm$ biotite $\pm$ pyroxene granodiorite to monzodiorite with some indication of a sanukitoid, mantle-melting signature. There are some indications at the level of exposure for a minor, more mafic (dioritic) magmas mixed with the later plutonic group of rocks that may indicate a more extensive mafic magmatic component at depth.

Intermediate to Felsic Intrusive Rocks and the Hemlo Gold Deposit

The nature and timing of intermediate to felsic intrusive activity is an important component in understanding the regional and detailed context of the Hemlo gold deposit from a number of perspectives. Firstly, understanding the nature of granitoid plutonism and its relationship to volcanism provides broad constraints on the tectonic environment. Secondly, it is possible that the formation of the Hemlo gold deposit is directly related to the emplacement and crystallization of intermediate to felsic igneous rocks.

Timing of Gold Mineralization at Hemlo

Understanding the significance of granitoid rocks for gold mineralization depends critically on understanding the timing of gold mineralization. This understanding remains elusive although most workers have interpreted that the deposit is deformed and metamorphosed to some extent and pre-dates the emplacement of the feldspar porphyry dikes (Muir, 1997 and references cited therein). The age of mineralized rocks provides a maximum constraint on the timing of mineralization. Regionally, metasedimentary rocks similar to those mineralized in the deposit area contain detrital zircons as young as 2693 Ma (Davis et al., 1998). Comparable ages have also been obtained for detrital zircons in metasedimentary rocks in the immediate deposit area (Davis, 1998). Mineralized quartz-feldspar porphyries may have similar ages but many of the zircons recovered from these samples are inherited (Davis, 1998). Davis (1998) also reports an age of 2677.2 ± 1.5 Ma for a "mineralized" aplite dike and notes that it is characterized by very low Th/U ratios which may reflect either a metamorphic origin or the low Th/U ratio of the whole rock. Additional uncertainty regarding the significance of this interpretation arises from the recognition of multiple types of remobilization of gold following the main mineralizing event (Bodycomb et al., 2000). Observations made as part of this study generally corroborate the interpretation that the feldspar porphyry dikes cut mineralization (Muir, 1997) although some alteration and pyritic mineralization post-dates the emplacement of the dikes. It is not clear if this late alteration is a distinct event that is unrelated to the main mineralization event or if the feldspar porphyry dikes can be regarded as late intermineral dikes. In either case, the dikes post-date the main mineralizing event and their age provides a minimum constraint on the timing of mineralization. Unfortunately, constraining the age of these dikes has proven problematic and the dikes exhibit some geochemical diversity that opens the possibility that they have more than one age. A quartz-feldspar porphyry dike has a complex zircon population, with the most collinear subset of data suggesting an age of 2684 ± 2 Ma but other fractions indicating the presence of an inherited component (Corfu and Muir, 1989a). A diorite dike also has a complex zircon population and a crudely constrained age of 2680 to 2690 Ma (Corfu and Muir, 1989a). A unit referred to as the Kusin's porphyry, which cuts ore and may be related to the feldspar porphyry dikes, has an age of 2680 ± 10 Ma based on relatively discordant data (Wasteneys, unpublished results reported in Johnston, 1996). Davis (1998) reports ages of 2677.5 ± 1.3 Ma for a feldspar porphyry dike that cuts ore. In addition to these

direct attempts to determine the age of dikes, their age can be inferred from potential correlation with plutons of known age outside the immediate deposit area. As discussed in a subsequent section, at least a subset of the Hemlo deposit area feldspar porphyry dikes may be genetically related to the Heron Bay pluton.

The foregoing relationships and interpretations suggest that the main episode of gold mineralization at Hemlo occurred between 2693 Ma and 2677-2690 Ma. Assuming that the age for the mineralized aplite dike is magmatic (Davis, 1998) and that the mineralization is not related to later remobilization (Bodycomb et al., 2000), the timing of mineralization would be even more tightly constrained to being synchronous with the youngest plutons (Gowan Lake and Fourbay Lake plutons). Due to the uncertainties in the origin of both the zircons and mineralization in the mineralized aplite dike, this constraint is regarded here to be somewhat speculative. Although the timing of gold mineralization is relatively tightly constrained in terms of absolute age to an interval of approximately 16 Ma, the rapid evolutionary development of the greenstone belt from its depositional stage to final tectonometamorphic configuration over this same narrow time interval renders these time constraints permissive of a broad range of mineral deposit models.

Regional Tectonic Context of the Hemlo Gold Deposit

The timing of gold mineralization at Hemlo (~2677 to 2693 Ma) broadly correlates with a change in the nature of granitoid magmatism. Earlier intrusive magmatic activity is syn- to pre-volcanic and is dominantly TTG-style magmatism interpreted to originate from the partial melting of tholeiitic basalt at lower crustal or upper mantle depths. This TTG-style magmatic activity is voluminous and requires a highly efficient mechanism to bury basalt to depths appropriate for the requisite metamorphic mineral assemblages and partial melting conditions. Subduction of basaltic crust is the most efficient mechanism to generate such large volumes of TTG magma and is consistent with interpretations of development of broadly coeval volcanic rocks of the Hemlo greenstone belt in an oceanic, arc environment (Polat et al., 1998).

In contrast, the youngest plutons have affinities to the sanukitoid suite and are interpreted to originate through the partial melting of metasomatized mantle. Components of some of the earliest plutons of the later plutonic group (2684 to 2690 Ma) may display affinities with either the TTG or sanukitoid suites and may represent a transitional stage. The uniformity in ages of sanukitoid suite plutons across much of the southern Superior province suggests that this be a regional scale event marking the termination of active subduction processes and leading to the stabilization of this portion of the Superior Province (Beakhouse et al., 1999).

The transitional magmatic stage postulated above is interpreted to be synchronous with regional folding of the greenstone belt. This deformation was followed shortly by decompression such that the inferred depth of emplacement of the youngest plutons is 3 to 4 kilometers less than that of the earlier plutons of the later plutonic group. The

sedimentary record of this decompression may be recorded in the Quetico subprovince to the north of the Manitouwadge greenstone belt.

The absolute timing of the Hemlo gold deposit is relatively tightly constrained but cannot in itself rule out many of the hypotheses that have been proposed for the formation of the deposit. This problem arises, in part, because of the rapid evolutionary development of the greenstone belt from its depositional stage to its final tectonometamorphic configuration over a similar period of time. Irrespective of its ultimate origin, the Hemlo gold deposit appears to have formed within several million years of a profound transition in the magmatic and tectonic evolutionary development of this part of the Superior Province. Aspects of this transition, which help define the regional context of the Hemlo gold deposit and some of which may have direct implications for the origin of the deposit, include:

The deposit was formed at, or shortly following, the termination of magmatic activity interpreted to be related to the subduction of basaltic crust. Subduction-related magmatism including arc volcanism (Polat et al., 1998) and TTG suite plutonism may have developed in a dominantly oceanic environment and is the major juvenile crust forming event in this portion of the Superior Province.

The deposit was formed during, or shortly before, a magmatic event characterized by a progressively increasing sanukitoid suite (melting of metasomatized mantle) component and decreasing TTG (melting of subducted basaltic crust). The extraction of the late plutons from variously metasomatized mantle is the last major Archean juvenile crust forming event, both locally and regionally and may be related to attainment of thermal equilibrium following the termination of subduction (Beakhouse et al., 1999).

The mantle-derived plutonic rocks are geochemically distinct from the earlier basaltic crust-derived plutonic rocks. The younger plutons also display a tendency to being more intrinsically oxidized than earlier plutons.

Although the distribution of different petrogenetic varieties of granitoid rocks across the Superior Province is poorly understood, the Hemlo greenstone belt area may have an anomalous abundance of late, mantle-derived, intermediate to felsic magmatic rocks.

The transition in magmatic style is interpreted to be a consequence of transition from a subduction-dominated tectonic regime to a post-subduction regime culminating in the stabilization of the crust in the southern Superior Province. A number of explanations are possible to explain the cessation of subduction including subduction polarity reversal, migration of subduction zone or collisional orogeny. Distinguishing between these possible interpretations requires a more regional study although attendant regional scale folding followed by decompression of the crust may indicate uplift and subsequent erosion which is most easily reconciled with a collisional orogenic model.

Possible Direct Association of Gold and Intermediate to Felsic Intrusive Rocks

There is no conclusive evidence linking the formation of the Hemlo gold deposit specifically to intermediate to felsic magmatism in the Hemlo greenstone belt although the data are permissive of such a relationship. The alteration assemblages and geochemical characteristics of the deposit are consistent with the presence of a significant magmatic component within the fluids responsible for mineralization and alteration (Bodycomb et al., 2000). For these reasons, it is appropriate to develop and test working hypotheses that link the formation of Archean lode gold deposits with intermediate to felsic plutonic activity. The ensuing discussion evaluates a previously published magmatic models for the Hemlo gold deposit, introduces a new specific model for the Hemlo deposit and discusses a general working hypothesis for the formation of magmatic-related gold deposits in the Superior Province.

Moose Lake Porphyry Models

Several models invoking a direct association of the Hemlo gold deposit with a felsic magmatic system have focused on the Moose Lake porphyry as the magmatic system with related porphyry-type mineralization (Kuhns, 1988, Kuhns et al., 1994; Johnston, 1996). The interpretation offered here that the Moose Lake porphyry represents an endogenous volcanic dome is inconsistent with some aspects of these porphyry models. It is still possible that the gold mineralization might be related to this magmatic system but the interpretation offered here would require that the mineralization be epithermal and that the Moose Lake porphyry be the volcanic component of a subvolcanic intrusive system that mineralized its own volcanic ejecta. The mineralization would be essentially syngenetic in this model. In detail, evidence for structural control of certain alteration and mineralization (Muir, 1997) would require that an original syngenetic, epithermal deposit was extensively modified. The emphasis of this study did not allow for detailed evaluation of this hypothesis and it will not be discussed subsequently in this report.

Alternatively, mineralization could be directly related to magmatic activity more distant from the site of ore deposition at some time after deposition of the subsequently mineralized rocks and prior to, or during, the complex deformational history imposed on the deposit area. The principal candidates in this regard are components of the later plutonic group that were emplaced during regional folding of the greenstone belt. It is possible that some of the minor, medium grained intrusions (e.g. Botham Lake stock) are a manifestation of a deeper, relatively large pluton that is not exposed. An alternative hypothesis is that mineralization could be related to a magmatic volatile phase emanating from plutons emplaced adjacent to, rather than beneath the Hemlo deposit area as discussed below.

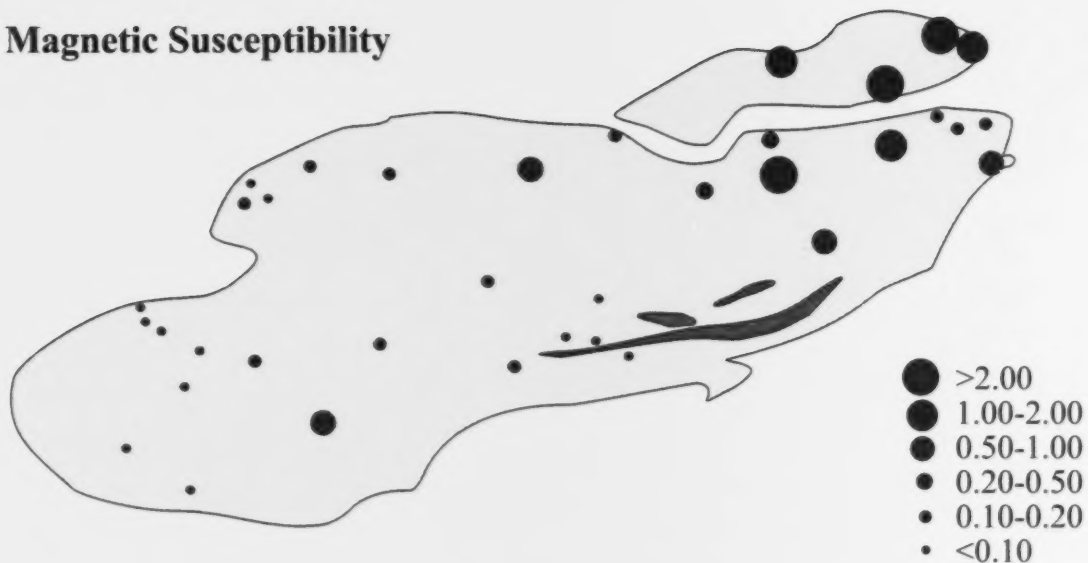
The Heron Bay Pluton and the Hemlo Gold Deposit: A Speculative Hypothesis

A speculative hypothesis relating the Heron Bay pluton to the Hemlo gold deposit is described below. The hypothesis is broadly consistent with relationships described for the Hemlo gold deposit area (Muir, 1997) and a number of observations and interpretations arising from this study:

- Several lines of evidence (physical continuity of the subporphyritic phase of the Heron Bay pluton with a dike-like apophyses (Plate 7), mineralogical and geochemical similarity of a subset of the feldspar porphyry dikes near the deposit to the plagioclase subporphyritic phase of the Heron Bay pluton, similar U-Pb ages) suggest that at least a subset of the abundant feldspar porphyry dikes from the Hemlo gold deposit area are genetically related to the Heron Bay pluton.
- The Heron Bay pluton is anomalous with respect to the later plutonic group in having a finer grained, plagioclase porphyritic component that is mineralogically and chemically similar to the medium grained phase of the same pluton. This porphyritic phase is concentrated near the margins and in the eastern portion of the pluton (Figure 57).
- The higher magnetic susceptibility associated with the eastern end of the pluton (Figure 57) is not associated with higher total iron abundance and may be related to subtle oxidation related to the evolution of a magmatic volatile phase (c.f., Candela, 1986).
- The textural contrast is interpreted to reflect the quenching of part of an otherwise uniform pluton, most likely in response to a decrease in hydrostatic pressure resulting in the release of a magmatic volatile phase.
- The emplacement of abundant, sub-concordant feldspar porphyry sheets centered near the Hemlo gold deposit (Figure 58) indicates a local extensional tectonic stage within an overall regional compressive deformational regime. The origin of extensional structures has not been emphasized in previous structural syntheses of the deposit area (Muir, 1997) but could reflect accommodation structures related to non-cylindrical folding or extensional jogs related to a component of simple shear.

The separation of a magmatic volatile phase from a magma is generally a function of two processes; 1) increasing water content of the melt due to crystallization of anhydrous mineral phases, and 2) spontaneous vesiculation in response to declining confining pressure (Whitney, 1989). Attention has recently been focused on the importance of the latter process in the formation of epithermal to shallow level porphyry mineralization where the magmatic volatile phase within a high level pluton is catastrophically released due to a rapid decrease in pressure due to sector collapse of overlying volcanoes (Sillitoe, 1994). Such a process might have a negligible effect at deeper levels but any process that could decrease hydrostatic pressure might be expected to promote the expulsion of a magmatic volatile phase from an H₂O-saturated pluton and quench the pluton.

Magnetic Susceptibility



Textures

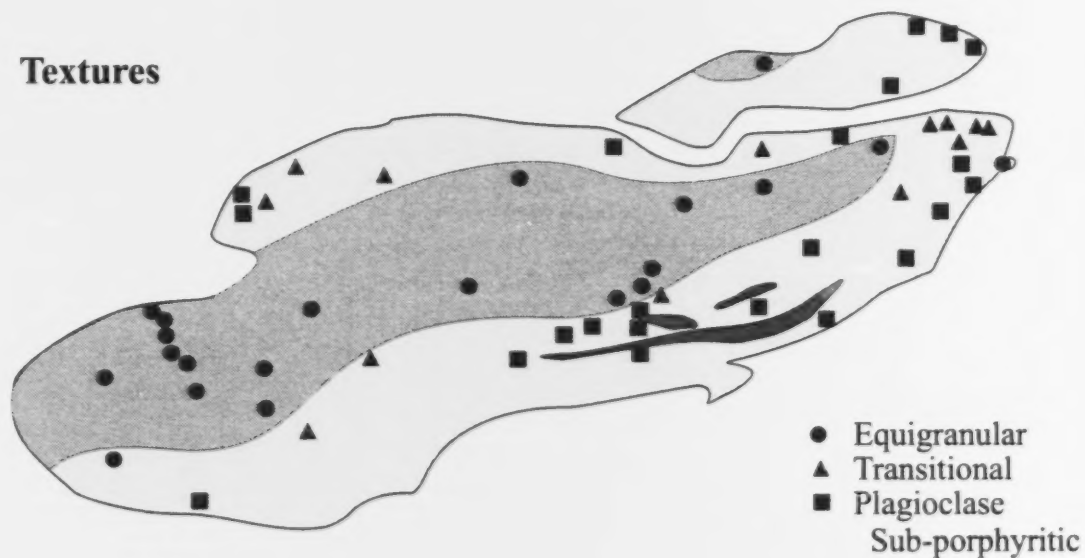


Figure 57. Variation in magnetic susceptibility and texture within the Heron Bay pluton. The different shading within the pluton in the lower diagram illustrates the distribution of medium grained, equigranular texture versus the transitional and plagioclase subporphyritic texture.

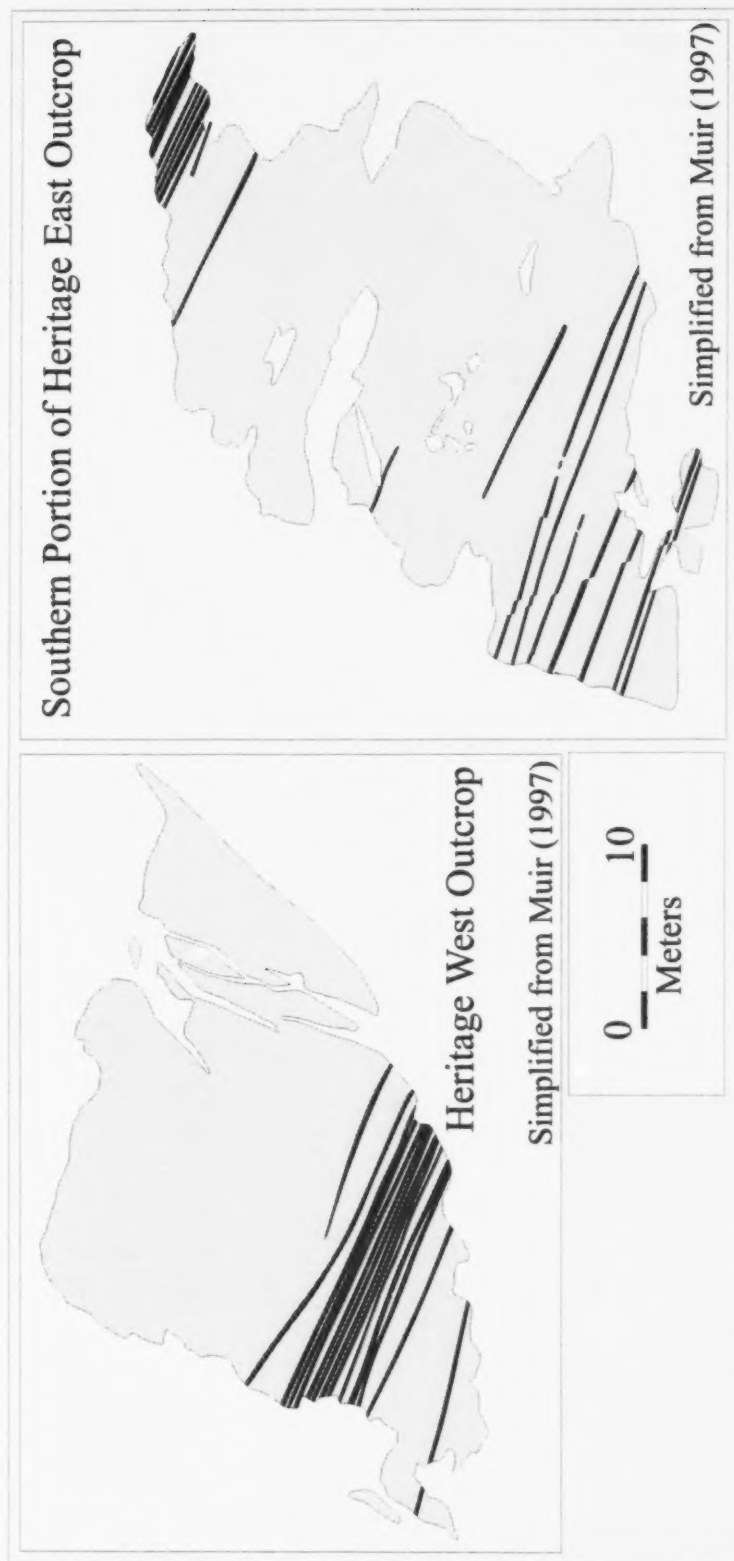


Figure 58. Distribution of feldspar porphyry and related dikes in portions of the Heritage outcrops located approximately 200 meters northwest of the Williams Mine headframe (simplified from mapping by Muir, 1997, Figure 27). In this area the dikes tend to occur as swarms (see also Plate 6f) but they are widely distributed in the Hemlo deposit area and are interpreted to have been emplaced into localized zones of extension.

The speculative model proposed here is based on the hypothesis that an extensional tectonic phase, synchronous with, and facilitating, the emplacement of the feldspar porphyry dikes, provides a mechanism to reduce the hydrostatic pressure. The effect of the creation of a lower hydrostatic pressure zone in the Hemlo deposit area was to segregate a magmatic volatile phase from the Heron Bay pluton and focus its flow into the deposit area. Other plutons were not affected either because they were completely crystalline, or not yet emplaced, or due to porosity/permeability constraints at the time of extension. The separation of a magmatic volatile phase from a portion of the pluton would depress the solidus and quench the pluton, giving rise to the plagioclase subporphyritic phase. The magmatic volatile phase would be an aqueous fluid enriched in potassium (and perhaps other incompatible elements) that would interact with rock in the volume of rock undergoing brittle extension, providing a mechanism to account for potassic, and perhaps other alteration. Evolution of both the fluid composition and geometry of fluid flow could produce the zonal alteration pattern reported for the Hemlo deposit area (Kuhns, 1988; Kuhns et al., 1994). A residual magmatic component of the Heron Bay, and perhaps other, plutons would ultimately intrude the evolving extensional structures to be quickly quenched giving rise to the feldspar porphyry dikes and inhibiting subsequent influx of fluids.

This model, if valid, has several important implications for the search for gold deposits comparable to those at Hemlo:

- The lateral egress of a magmatic volatile phase from the Heron Bay pluton requires special conditions and would otherwise normally be vertically directed. This interpretation implies that the map view at Hemlo might be similar to a section view in other deposits. The preservation of a Hemlo-type deposit at lower crustal levels as in the Hemlo belt may require special conditions that influence the crystallization and fluid generation of magmas. Extensional structures may play an important role both in influencing this behavior and serving to focus the flow of the expelled magmatic volatile phase. In some cases, magmatic fluids may be expelled laterally rather than being focused in and above the upper portions of plutons. Hemlo type deposits may also form above Heron Bay-type plutons at higher crustal levels. In certain respects, it might be best to look for magmatic gold deposits in areas where the magmatic products are not exposed.
- The association of gold mineralization with older, relatively massive quartz porphyritic units may be due the ductility contrast these units introduce to the stratigraphy which serves as a locus for the development of extensional structures that may focus fluid flow. In this respect, other rock types (e.g., chemical metasedimentary rocks) may serve a similar function although they may also provide an efficient chemical trap that influences the small-scale distribution of mineralization. It is possible that some of the deposits in the Beardmore-Geraldton belt (e.g., Bankfield Mine, MacLeod-Cockshutt Mine; Pye, 1951; Horwood and Pye, 1951) may be of this latter type.
- Textural variations within plutons displaying limited compositional variation should be considered as possible indicators of expulsion of a magmatic

volatile phase that could play a role in magmatic alteration/mineralization events. The mineralization could be proximal or distal to the source pluton.

The most useful exploration criteria for such deposits are:

- Presence of intermediate to high level magmas which have generated a magmatic volatile phase.
- Presence of units having markedly contrasting ductility which may serve to localize heterogeneous strain.
- Presence of extensional tectonic structures that could influence fluid flow, particularly where infilled with magmatic rocks indicating coeval extension and magmatism.
- Presence of alteration, particularly potassic alteration which may be detected by airborne spectrometer surveys, examination of stained slabs or lithogeochemistry.

It is emphasized here that a detailed evaluation of the deposit has not been carried out to test this hypothesis. The hypothesis outlined above links a number of regional and deposit scale observations and is broadly consistent with temporal and genetic relationships. The hypothesis may have application beyond the Hemlo greenstone belt and should, along with other hypotheses, be considered in attempts to understand the Hemlo gold deposit and locate similar deposits.

One aspect of this study that is difficult to reconcile with this hypothesis is the relatively weakly oxidized nature of the Heron Bay pluton. This characteristic is atypical of late plutons associated with the Hemlo greenstone belt and I-type granites in general. This may be due to interaction with sedimentary rocks, which is suggested by the presence of xenocrystic zircon comparable in age to those occurring within the greenstone belt. As discussed below, such a weakly oxidized nature may inhibit the potential of a pluton to carry metals to the point where they can be partitioned into a magmatic volatile phase such as is implicated in the formation of the Hemlo gold deposit.

Discussion of the Magma – Gold Connection

A variety of factors suggest that it is desirable to have a general working hypotheses linking gold mineralization to intermediate to felsic intrusive rocks:

- A variety of alteration types and lithophile metal associations within the Hemlo deposit area suggest a significant magmatic component for the fluids responsible for alteration and mineralization (Bodycomb et al., 2000).
- Available constraints on the timing of gold mineralization at Hemlo and the timing of late plutonic activity associated with the Hemlo greenstone belt suggest that mineralization and plutonism are broadly contemporaneous. This relationship is permissive of the hypothesis that the formation of the Hemlo gold deposit is genetically linked to evolution of a magmatic volatile phase from late plutons.

- Major gold-rich deposits in young, tectonically active zones are interpreted to be genetically related to plutons and their associated magmatic volatile phases (Sillitoe, 1997). Broadly uniformitarian hypotheses have been applied to many aspects of Superior Province geology and it seems reasonable to attempt to extend these comparisons to mineral deposits.

The characteristics of magmatic Au $\pm$ Cu $\pm$ Mo mineralization (based largely on studies of Cenozoic to Recent deposits) have been reviewed elsewhere (Burnham and Ohmoto, 1980; Candela, 1989; Sillitoe, 1997). Some of the processes and factors that have been implicated in the formation of these deposits include:

- Mineralization is related to volcano-plutonic arcs during, or immediately following, active subduction of oceanic lithosphere. Within this general constraint, mineralization occurs in a wide variety of crustal (continental, oceanic) and regional stress (extensional, compressional) regimes (Sillitoe, 1993).
- Mineralization is associated with a broad compositional spectrum of magmatic rocks although there is a tendency for deposits to be disproportionately associated with magmas of shoshonitic or alkaline affinity (Müller and Groves, 1993; Sillitoe, 1997).
- Magmas implicated in mineralization are highly oxidized. This highly oxidized character has the potential to stabilize sulphate (Carroll and Rutherford, 1985) and inhibits the formation of sulphides which would sequester chalcophile elements making them unavailable for partitioning into a subsequently evolved magmatic volatile phase (Candela, 1989).
- The ore metals are concentrated in the magmatic volatile phase (MVP) relative to the source granitic magma (Candela and Holland, 1984, 1986). The MVP may also be enriched in potassium and other incompatible lithophile elements. The MVP interacts with the pluton and/or the country rock and is a major component of the fluids responsible for both mineralization and alteration.
- Many deposits are formed at shallow depths (<1.5 kilometers). At these depths, the solubility of water in magma decreases rapidly with depth (Burnham and Ohmoto, 1980) such that any reduction in pressure due to either upward movement of magma or modification of surface morphology (e.g., sector collapse of overlying volcanoes, Sillitoe, 1994) can trigger H₂O oversaturation and formation of a MVP. Furthermore, at these depths, the hydrostatic pressures attendant with the formation of a MVP can overcome lithostatic pressure resulting in widespread brecciation. The mechanical energy associated with this process may be capable of producing explosive volcanism and brecciation at shallow (<2 km) depths and fracturing wall rocks to depths of 4 to 5 kilometers (Burnham, 1985; Burnham and Ohmoto, 1980). The resultant porosity/permeability serves to focus flow of the MVP and result in the characteristic stockwork style of mineralization.

The magmatic linkage of many young gold-rich deposits is widely accepted but there is no such consensus as applied to Archean gold deposits. Uniformitarian, plate tectonic

hypotheses, in which Archean greenstone belts and associated granitic rocks are analogous to more recent volcano-plutonic arcs that host magmatic Au-Cu-Mo deposits, are widely advocated. Several authors have implicated intermediate to felsic magmas with the formation of certain Archean gold deposits but relationships are rarely as compelling as they are in many younger, gold-rich deposits. This may, in part, be a function of the incompatible behavior of gold in the presence of sulphur-bearing fluids that may serve to redistribute gold into late structures and obscure primary relationships. It is also possible that the nature of preservation of Archean crust plays a role in concealing possible relationships between gold mineralization and intermediate to felsic magmatism.

The physical/chemical processes described above are independent of time. The general compositional spectra of Archean and Phanerozoic intermediate to felsic magmas are similar although the proportion of TTG or adakitic magmas may be somewhat higher in the Archean suggesting a secular decrease in slab-melting and/or increase in mantle-wedge melting (Drummond and Defant, 1990). The latest Archean magmatism includes a component of LILE-enriched, mantle-derived magmas (part of the later plutonic group of this study) that may be spatially and temporally related to gold mineralization and is similar to a component of Phanerozoic magmatic arcs (Sutcliffe et al., 1993).

One major difference between Late Archean magmatism and that occurring in Cenozoic to Recent arcs is the erosional level with the younger deposits formed at shallow depths and commonly exposed by rapid erosion in tropical areas (Sillitoe, 1997)^{*}. Hornblende barometry carried out as part of this investigation suggests pressures of 3 to 4.5 kilobars, corresponding to depths of approximately 9 to 14 kilometers. Comparable to somewhat higher pressures are reported from the northern Superior Province (Stone, 2000) but more work is required to establish the depth of emplacement of late plutons across the Superior Province. At these greater pressures, it is less likely that the smaller volume change accompanying release of a MVP (Burnham and Ohmoto, 1980) could overcome lithostatic pressure and form breccias and fracture systems as it does at lower pressures. Unless some other process (such as migration of MVP into extensional tectonic settings near the pluton as proposed for the Heron Bay pluton hypothesis) operates, this may result in the MVP reacting with large volumes of rock, primarily within the pluton, and not being sufficiently focused and concentrated to form an economic deposit (c.f., magmatic vapor-disperse system – Candela, 1991). The ubiquitous hydrous deuteric alteration assemblages reported in this study and the presence of many small, sub-economic deposits in some plutons (e.g., Terrace Bay Batholith, Marmont, 1984) may be a manifestation of this process operating on some level.

The foregoing suggests that models relating mineralization and magmatism as developed for the Phanerozoic may apply, with modifications, to the Archean deposits of the Superior Province. The principal modification is a requirement for some tectonically induced structure to provide the porosity – permeability and possibly pressure gradient at

^{*} This discussion pertains to Late Archean plutons that may be spatially and temporally related to gold mineralization. Older, syn-volcanic plutons deformed along with the greenstone belt may have formed at depths appropriate for development of breccias and fracture systems as discussed above.

depths where lithostatic pressures preclude development of MVP-induced brecciation. This modification may reconcile the magmatic model with the long recognized association of gold mineralization with regional-scale, generally east trending regional faults and in particular with east south-east and east-northeast trending segments associated with these systems (Fyon et al., 1992). Within a modified magmatic model for gold mineralization, these major structures may play two roles. Firstly, these zones of crustal weakness may serve to localize the emplacement of late plutons implicated in gold mineralization. Secondly, localized extension in favorably oriented fault segments or splays accompanying late transcurrent movement on these fault systems may create a favorable porosity-permeability environment for focussing magmatic volatile phases originating in intermediate to deeper level plutons.

Conclusions

Intermediate to felsic intrusive rocks associated with the Hemlo greenstone belt were emplaced over an interval of approximately 45 Ma and record a variety of secular evolutionary trends. The earlier plutons are pre- to syn-volcanic and are interpreted to indicate that they originate through the partial melting of subducted basaltic crust. Later plutons post-date volcanism and are interpreted to indicate an increasingly important contribution of magmas produced by direct partial melting of mantle that was metasomatically enriched in a wide range of incompatible elements during the earlier subduction-dominated regime. The transition in the nature of magmatic rocks is interpreted to be a consequence of the termination of subduction in this part of the Superior Province and the initiation of processes that culminated in stabilization of the craton.

Gold mineralization is temporally associated with this transition and may be genetically related to late plutons. Many of the later plutons are relatively highly oxidized and are good candidates for generating metal-rich magmatic volatile phases. The two most highly oxidized plutons associated with the Hemlo greenstone belt (Cedar Creek and Botham stocks) are closely spatially associated with the Hemlo gold deposit and may be a vector for exploration for similar deposits. The Heron Bay pluton exhibits certain characteristics and relationships that suggest it may have yielded a magmatic volatile phase concomitant with localized tectonic extension that focused magmatic hydrothermal alteration and mineralization, however the relatively reduced nature of this pluton is difficult to reconcile with this hypothesis. Regardless of which pluton may be implicated in the formation of the Hemlo gold deposit, tectonically-induced porosity – permeability concomitant with proximal formation of a metalliferous magmatic volatile phase is proposed as a general hypothesis that should, along with other hypotheses, be considered in exploration for similar deposits.

Some of the concepts that should be considered in development and testing of this hypothesis, and its application to exploration for similar deposits, include:

- *Presence of late, mantle-derived plutons* – Plutons of this nature are relatively abundant in association with the Hemlo greenstone belt and perhaps in other

gold camps (e.g., Kirkland Lake; Levesque, 1994; Levesque et al., 1991). Further regional investigations of late plutons within the Superior Province are required to understand the extent and distribution of these plutons to evaluate whether their abundance in gold camps may be anomalous.

- *Oxidation state of plutons* – The most proximal plutons to the Hemlo gold deposit (Cedar Creek and Botham stocks) are the most oxidized plutons associated with the Hemlo greenstone belt and, regardless of the origin of this characteristic, may be an exploration vector that can be applied to other areas. On theoretical grounds, highly oxidized plutons are the best candidates for being parental to oxidized, metalliferous magmatic volatile phases. An association between oxidized magmas and gold mineralization has been proposed by others (Hattori, 1987; Rowins et al., 1991) and may be an important control on the distribution of gold mineralization. Although relatively sophisticated petrographic and mineral chemical studies are required for comprehensive investigation, the combination of basic petrography, magnetic susceptibility and whole rock major element analysis offers potential as a practical, inexpensive means of assessing the oxidation state of intermediate to felsic plutons.
- *Depth of Emplacement* – The crystallization of plutons at pressures in excess of 2 kilobars will inhibit the formation of breccias and fracture zones that exert a major influence on the distribution of magmatic hydrothermal alteration and mineralization at lower pressures. Further studies are required to address the possibility that some plutons may be emplaced at sufficiently high levels to permit the development of classic porphyry style deposits. Plutons emplaced at deeper levels may be associated with different styles of mineralization.
- *Hydrothermal alteration* – The nature of magmatic hydrothermal alteration at shallow depths should be comparable to that described for Cenozoic to Recent magmatic mineralization. At deeper levels that characterize portions of the Superior Province, the nature of alteration and its geometric configuration may be very different and requires further study. The potassic alteration at Hemlo, which can be identified from hydrofluoric acid etched – sodium cobaltinitrate stained slabs, whole rock geochemistry and airborne spectrometer surveys, may be an exploration vector for similar deposits.
- *Proximity and temporal relationship of plutons to tectonically-induced porosity / permeability* – At depths in excess of 5 to 6 kilometers, the porosity and permeability required to effectively focus the flow of magmatic hydrothermal fluids will be created primarily by tectonic deformation. Zones of extension may be especially effective as they may create hydrostatic pressure gradients. Favorable environments may include zones of heterogeneous strain associated with heterolithic zones having high ductility contrast and extension segments and splays on major faults but other factors may also be important. Concomitant magmatism and extension (established from field relationships and geochronology) may be especially favorable.

A variety of models have been proposed for Archean gold deposits and it is unlikely that one model can account for all deposits. Consequently, a multiple working hypothesis approach, that includes magmatic and modified magmatic models, is considered most appropriate.

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Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Cedar Lake Pluton

Unit	Main Phase													
Samples	7004A	7006B	7007	7009	7010	7013	7016	7018A	7033A	7034	7038	7067	7219	7262
qtz	19.4	19.0	17.6	18.3	15.9	17.4	23.0	20.0	18.8	19.6	14.8	24.2	20.8	12.6
kfeld	10.6	22.3	6.4	21.5	10.2	6.7	15.9	13.7	10.3	6.9	11.3	12.1	14.1	8.4
plag	58.0	41.2	56.0	43.2	59.4	58.9	49.6	57.0	56.4	58.8	60.8	44.2	48.3	63.0
pyx														6.0
hbl	6.5	11.9	12.0	12.4	9.5	12.5	6.5	7.0	9.1	6.9	8.4	17.2	12.3	5.5
biot	3.8	4.1	6.0	3.6	3.9	3.0	4.5	1.5	3.6	6.1	2.6		3.5	
epid	0.2	0.4	tr	0.1	tr		tr	tr		tr	tr	0.6	0.1	0.1
mt	1.0	0.4	0.8	0.5	tr	0.4	0.2	0.2	0.6	0.2	0.1	0.4	0.1	0.4
chl	tr		tr	tr					0.4	1.1	1.5	1.0	0.2	3.0
sph	0.5	0.5	1.2	0.4	1.1	1.1	0.3	0.5	0.8	0.4	0.5	0.3	0.5	0.8
apat	tr	0.1	tr	tr	tr	tr	tr	0.1	tr	tr	tr	tr	0.1	0.1
zir	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	
musc														0.1
sulph														tr
carb		0.1												
Q/QPK	22%	23%	22%	22%	19%	21%	26%	22%	22%	23%	17%	30%	25%	15%
P/PK	85%	65%	90%	67%	85%	90%	76%	81%	85%	89%	84%	79%	77%	88%
Cl	10.5	16.4	18.0	16.1	13.4	15.5	11.0	8.5	13.1	14.1	12.5	18.8	16.1	8.6
hb/hb+bt+cl	63%	74%	67%	77%	71%	81%	59%	82%	69%	49%	67%	95%	77%	65%

Modal analyses are based on point counts of thin sections with relative proportions of quartz, plagioclase and k-feldspar determined from point counting of stained, cut slabs.

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Cedar Lake Pluton

Unit	Cedar Lake Pluton											
	Main Phase		Mag Granodiorite			Diorite					Dike	
Samples	7263	7292	7032	7205	7004B	7008B	7009B	7018B	7033B	7217	7205B	
qtz	22.5	22.0	19.9	18.1	6.5	tr	8.7	3.5	5.2	tr	29.4	
kfeld	9.1	17.6	10.0	14.6	16.8	1.0	8.6	34.6	16.4	7.8	32.2	
plag	58.5	48.4	60.8	53.4	42.3	48.0	40.2	32.4	43.9	57.2	36.3	
pyx	3.5											
hbl	0.5	7.5	2.0	10.1	28.0	44.0	40.5	24.5	30.3	28.9		
biot		0.8	5.7	1.8	5.0	5.5		3.0	2.5	4.6	0.8	
epid	0.5	0.2	tr	0.4	0.1	tr	1.5	1.0	0.4	0.1	0.7	
mt	tr	0.1	0.8	0.7		tr	tr		0.2	tr	0.6	
chl	5.0	3.2							1.1	0.9	tr	
sph	0.4	0.2	0.7	0.8	1.1	1.1	0.4	0.8	1.1	0.9	tr	
apat	tr	tr	0.1	0.1	0.2	0.4	0.1	0.2	tr	0.1		
zir	tr	tr	tr	tr	tr	tr			tr	tr	tr	
musc												
sulph	tr			tr								
carb												
Q/QPK	25%	25%	22%	21%	10%	0%	15%	5%	8%	0%	30%	
P/PK	87%	73%	86%	79%	72%	98%	82%	48%	73%	88%	53%	
Cl	6.0	11.7	7.7	12.3	33.1	49.5	42.0	28.5	33.0	33.6	1.4	
hb/hb+bt+cl	9%	65%	26%	85%	85%	89%	100%	89%	92%	86%	0%	

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Heron Bay Pluton

Medium Grained Phases

Unit																
Samples	7094	7123	7127	7133	7134	7135	7136	7137	7152	7153	7155	7265	7266	7267	7268	7329
qtz	23.6	25.3	22.3	25.8	24.2	23.2	24.5	21.9	23.1	19.8	15.8	27.1	22.0	21.1	21.2	23.6
kfeld	12.3	21.7	16.0	16.0	19.1	24.1	13.5	23.5	12.8	13.5	11.6	21.5	17.4	11.8	11.0	7.9
plag	51.6	43.5	50.7	47.2	43.3	38.7	46.5	38.6	49.6	56.7	55.6	44.9	52.1	51.6	59.8	56.0
pyx																
hbl	6.5	6.1	5.5	4.5	6.3	7.0	6.5	8.4	6.0	5.9	14.9	3.2	5.0	10.8	4.5	7.8
biot	4.1	2.1	4.4	0.1	4.8	4.9	7.8	5.8	5.0	1.6	0.4	0.5	2.8	3.8	1.4	4.2
epid	1.4	0.4	0.5	2.6	1.8	1.6	0.7	1.2	2.6	1.3	0.3	0.5	0.3	0.3	0.4	0.1
mt	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
chl		0.8	0.1	3.4	0.1	0.1	0.2	0.3	0.5	1.0	1.2	2.0	0.2	0.4	1.6	0.3
sph	0.5	0.1	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.2	0.2	0.3	0.2	0.2	0.1	0.1
apat	tr	tr	0.1	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
zlr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
musc																
sulph																
carb																
Q/OPK	27%	28%	25%	29%	28%	27%	29%	26%	27%	22%	19%	29%	24%	25%	23%	27%
P/PK	81%	67%	76%	75%	69%	62%	78%	62%	79%	81%	83%	68%	75%	81%	84%	88%
Cl	12.0	9.4	10.5	10.6	13.0	13.6	15.2	15.7	14.1	9.8	16.8	6.2	8.3	15.3	7.9	12.4
hb/hb+bt+cl	61%	68%	55%	56%	56%	58%	45%	58%	52%	69%	90%	56%	63%	72%	60%	63%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Unit	Heron Bay Pluton																	
	Transitional Phases							Plagioclase Subporphyritic Phases									Plag Subporph Phases	
Samples	7097	7099	7117	7154	7156	7157	7158	7159	7269	7071	7096	7118	7119	7128	7151	7264	7122	
qtz	21.7	25.6	21.3	20.6	24.4	19.1	21.5	21.5	19.7	21.2	21.9	18.9	14.6	23.5	22.1	19.8	19.4	
kfeld	8.2	12.8	6.8	12.5	15.5	18.3	15.5	17.4	18.8	15.9	15.8	11.3	8.8	16.3	15.3	12.6	14.1	
plag	60.6	53.1	47.9	56.4	41.3	49.6	49.0	43.9	51.0	51.4	49.8	45.3	49.5	50.5	47.5	57.6	54.5	
pyx																		
hbl	6.4	4.5	14.9	7.5	11.8	9.5	9.2	13.1	5.0	5.6	5.6	17.5	23.6	5.4	10.1	5.5	5.4	
biot		2.6	1.5	1.2	3.9	1.2	2.3	3.2	0.5	3.4	4.9	0.5	tr	3.4	0.1	3.6	4.3	
epid	0.4	0.1	1.4	0.8	1.8	0.8	0.4	0.4	1.3	0.3	1.4	0.8	1.3	0.3	1.1	0.2	1.4	
mt	tr	tr		tr	tr	tr	tr	tr	tr	tr	0.2			tr	tr	0.1	tr	
chl	2.6	0.9	6.0	0.8	0.8	1.3	2.0	0.4	3.5	2.0		5.5	2.0	0.2	3.4	0.4	0.5	
sph	0.1	0.4	0.2	0.2	0.4	0.2	0.1	0.1	0.2	0.2	0.4	0.2	0.2	0.3	0.4	0.2	0.4	
apat	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	0.1	tr	tr	tr	
zlr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr		tr	tr	tr	tr	tr	tr	
musc																		
sulph			tr		tr	tr	tr		tr					tr				
carb					tr													
Q/QPK	24%	28%	28%	23%	30%	22%	25%	26%	22%	24%	25%	25%	20%	26%	26%	22%	22%	
P/PK	88%	81%	88%	82%	73%	73%	76%	72%	73%	76%	76%	80%	85%	76%	76%	82%	79%	
Cl	9.4	8.1	23.8	10.3	18.3	12.8	13.9	17.1	10.3	11.3	11.9	24.3	26.9	9.3	14.7	9.7	11.6	
hb/hb+bt+cl	71%	56%	67%	79%	72%	79%	68%	78%	56%	51%	53%	74%	92%	60%	74%	58%	53%	

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Gowan Lake Pluton

Equigranular Phases

Unit	7181	7183	7184	7230	7231	7252	7243	7250
Samples	7181	7183	7184	7230	7231	7252	7243	7250
qtz	12.7	13.1	5.6	4.6	15.3	8.5	15.0	17.7
kfeld	22.3	19.0	11.1	19.1	18.5	23.3	18.8	20.0
plag	44.5	40.9	52.8	52.8	46.7	45.7	41.2	39.3
pyx		1.0	0.9					
hbl	12.0	16.0	14.6	17.1	12.4	18.4	14.5	15.8
biot	7.0	8.0	13.9	4.0	5.8	2.5	9.5	4.6
epid	0.2	0.1	tr	0.3	0.4	0.3	0.2	0.4
mt	1.0	1.6	1.0	1.5	0.8	0.5	0.4	1.1
chl		tr	tr	tr	tr	0.6	tr	0.6
sph	0.1			0.4	tr	0.2	0.3	0.4
apat	0.2	0.3	0.1	0.2	0.1	tr	0.1	0.1
zir	tr	tr		tr		tr		tr
musc								
sulph					tr			
carb								
Q/QPK	16%	18%	8%	6%	19%	11%	20%	23%
P/PK	67%	68%	83%	73%	72%	66%	69%	66%
Cl	19.2	24.1	28.5	21.4	18.6	21.8	24.2	21.4
hb/hb+bt+cl	63%	67%	51%	81%	68%	86%	60%	75%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Unit	Gowan Lake Pluton										Gowan Lake Pluton		
	Microcline Megacrystic Phases										Enclaves		
Samples	7160	7173	7175	7233	7234	7235	7236	7237			7233B	7235B	7236B
qtz	6.3	3.4	tr	9.2	6.2	13.2	18.0	13.3			1.7	tr	7.4
kfeld	21.2	28.6	17.4	21.4	19.4	19.9	17.2	23.4			29.9	15.6	27.9
plag	43.0	52.0	55.1	45.9	51.9	40.5	46.8	41.3			25.9	23.4	26.7
pyx													
hbl	26.5	11.2	20.9	18.5	15.8	17.6	9.8	18.1			39.8	55.0	36.5
biot				3.7	2.2	7.2	3.4	2.0			1.2	4.7	1.0
epid	0.4	0.7	0.6	0.3	0.5	0.2	0.4	0.3			0.3	0.3	0.1
mt	0.5	1.0	0.6	0.6	0.5	0.5	0.5	0.6			0.2	tr	tr
chl	1.5	2.5	5.1	3.0	3.0	0.4	3.3	0.7			0.5	1.0	tr
sph	0.6	0.6	0.3	0.3	0.4	0.4	0.5	0.3			0.3		0.3
apat	tr	tr		0.1	0.1	0.1	0.1	tr			0.1	tr	0.1
zir	tr			tr	tr	tr	tr	tr				tr	tr
musc													
sulph													
carb			tr								0.1		
Q/QPK	9%	4%	0%	12%	8%	18%	22%	17%			3%	0%	12%
P/PK	67%	65%	76%	68%	73%	67%	73%	64%			46%	60%	49%
Cl	28.4	14.4	26.6	22.5	21.5	25.4	16.9	21.1			41.8	61.0	37.6
hb/hb+bt+cl	95%	82%	80%	83%	75%	70%	59%	87%			96%	91%	97%

Fourbay Lake Pluton

Main Phase

Cedar Creek Stock

Main Phase

Dike

Unit	7238	7239	7240	7241	7294	7295	7296	7297	7298	7297B
Samples										
qtz	11.1	14.3	10.4	12.5	24.1	24.8	23.7	26.6	25.0	31.7
kfeld	18.2	18.5	13.5	20.9	18.5	14.8	20.0	15.6	20.4	29.7
plag	49.7	51.2	55.6	49.9	49.9	52.4	47.3	49.3	47.1	37.6
pyx		0.1	1.9	tr						
hbl	16.6	9.5	13.5	12.1	0.8	1.4	3.4	1.5	2.5	
biot	2.2	4.4	4.0	3.9	4.7	5.2	3.3	5.5	2.5	
epid	tr	tr	tr	tr	0.2	0.2	0.2	0.2	0.5	0.2
mt	1.0	1.6	1.0	0.5	1.1	0.7	0.9	0.7	0.6	0.3
chl	0.7	tr	tr				0.8	tr	1.0	0.3
sph	0.4	0.2	tr	0.1	0.7	0.5	0.4	0.6	0.4	tr
apat	0.1	0.2	0.1	0.1	tr	tr	tr	tr	tr	
zir	tr	tr	tr		tr	tr	tr	tr	tr	
musc					tr				tr	0.2
sulph					tr					
carb										
Q/QPK	14%	17%	13%	15%	26%	27%	26%	29%	27%	32%
P/PK	73%	73%	80%	70%	73%	78%	70%	76%	70%	56%
Cl	19.5	13.9	17.5	16.0	5.7	6.8	7.7	7.2	6.5	0.5
hb/hb+bt+cl	85%	68%	77%	76%	15%	21%	45%	21%	42%	0%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Unit	Dotted Lake Pluton											
	Main Phase											External
Samples	7045	7050	7056	7079	7302	7303	7306	7308	7310	7312	7313	7305
qtz	24.0	23.2	28.9	27.3	29.2	25.1	28.8	23.3	30.4	30.1	26.4	22.5
kfeld	14.4	16.4	7.7	11.6	4.9	9.9	8.4	9.3	15.7	13.2	13.2	4.3
plag	57.6	56.9	59.9	55.3	63.4	54.5	55.7	60.4	51.9	50.7	54.8	59.6
pyx												
hbl			0.9				tr					
biot	2.3	1.9	2.1	5.1	1.0	8.0	tr	5.6	tr	4.9	0.5	12.5
epid	0.5	0.6	0.2	0.3	0.2	1.4	0.5	0.6	0.5	0.5	0.5	0.6
mt	0.4	0.4	tr	0.3	0.1			0.5		0.4	tr	tr
chl	0.2			tr	1.0	1.0	6.5	tr	1.3	0.1	4.5	tr
sph	0.5	0.3	0.3	0.1	tr	tr	tr	tr	0.1	tr	tr	tr
apat	tr	tr	tr	tr	tr	0.1	tr	0.3	0.1	0.1	tr	0.4
zlr	tr	tr	tr	tr			tr	tr	tr	tr	tr	tr
musc	0.1	0.3			0.2	tr			tr	tr	tr	tr
sulph												
carb								tr	tr	tr	tr	
Q/QPK	25%	24%	30%	29%	30%	28%	31%	25%	31%	32%	28%	26%
P/PK	80%	78%	89%	83%	93%	85%	87%	87%	77%	79%	81%	93%
Cl	3.0	2.5	3.2	5.4	2.2	10.4	7.0	6.2	1.8	5.5	5.5	13.1
hb/hb+bt+cl	0%	0%	30%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Unit	Picture Island Stock			Botham Stock		Melgund Stock		
	7222	7223	7224	7066	7301	7129	7130	7131
Samples	30.7	32.6	27.9	22.0	22.6	8.0	10.2	8.5
qtz	11.2	23.0	14.5	16.5	9.4	5.8	6.6	6.2
kfeld	51.1	40.4	47.8	53.0	62.0	59.2	56.2	62.8
plag								
pyx								
hbl	0.6	0.4	8.1	6.5	4.1	19.8	24.0	20.5
biot	0.4	0.4	0.4	0.9	0.3	6.2	tr	0.1
epid	0.3		tr	0.9	0.5	0.4	0.5	0.8
mt	5.4	3.0	1.1		0.9	tr	tr	tr
chl	0.2	0.1	0.1	0.2	0.2	tr	2.0	0.4
sph	0.1	tr	tr	tr	tr	0.5	0.5	0.5
apat	tr		tr	tr	tr	0.1	tr	0.1
zir								
musc								
sulph		0.1	0.1		tr	tr	tr	0.1
carb	tr	tr		tr				
Q/QPK	33%	34%	31%	24%	24%	11%	14%	11%
P/PK	82%	64%	77%	76%	87%	91%	89%	91%
Cl	6.4	3.8	9.6	7.4	5.3	26.4	26.5	21.8
hb/hb+bt+cl	0%	0%	0%	0%	0%	76%	92%	98%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Unit	Musher Lake Pluton					Ogilvie Ist Stock		Satellite Stock		
								dior	grdr	por-grdr
Samples	7075	7093	7207	7261	7813	7324	7325	7257	7260	7259
qtz	17.9	22.8	21.6	18.6	21.9	23.9	23.6	2.4	20.6	17.4
kfeld	7.0	7.3	17.4	12.4	10.6	4.3	2.6	18.5	8.1	11.0
plag	53.1	51.4	44.0	46.5	43.0	57.3	60.9	38.6	60.8	63.1
pyx										
hbl	9.5	12.5	6.0	9.0	12.5	0.2		38.5	4.5	6.0
biot	11.4	2.4	2.4	tr	10.5	2.8	9.1	0.9	3.7	1.0
epid	0.6	0.4	0.3	0.2	0.1	1.3	0.5	0.1	0.2	0.1
mt	0.3	0.1	0.5	tr	0.2			tr	1.0	0.5
chl		2.5	7.1	12.0	tr	10.0	2.6	0.7	0.8	0.5
sph	0.2	0.6	0.6	1.2	1.1	0.1	0.2	0.3	0.3	0.4
apat	tr	tr	0.1	0.1	0.1	0.1	0.1	tr	tr	tr
zlr	tr	tr	tr	tr	tr	tr	tr		tr	
musc										
sulph			tr	tr			0.4			
carb										
Q/QPK	23%	28%	26%	24%	29%	28%	27%	4%	23%	19%
P/PK	88%	88%	72%	79%	80%	93%	96%	68%	88%	85%
Cl	21.5	17.8	15.8	21.2	23.1	14.3	12.2	40.2	9.2	7.6
hb/hb+bt+cl	45%	72%	39%	43%	54%	2%	0%	96%	50%	80%

Unit	Terrace Bay Batholith				White River Pluton			
	Inclave	Granodiorite						
Samples	7171B	7171	7172		7040	7041	7042	7043
qtz	1.5	25.2	24.4				3.0	5.5
kfeld	5.1	16.5	18.8		15.3	7.1	17.0	13.8
plag	66.4	45.3	50.8		35.4	40.4	47.1	49.7
pyx								
hbl	19.8	8.4	4.0		48.8	50.8	29.5	27.5
biot	5.9	2.2	0.2				0.5	
epid	tr	0.1	tr			0.5	0.9	tr
mt	1.2	1.4	0.5					
chl	tr	0.1	1.2		tr	0.6	1.0	3.4
sph	0.1	0.8	0.1		0.4	0.5	1.0	0.1
apat	tr	tr	tr			tr	tr	tr
zlr		tr	tr				tr	
musc								
sulph					0.1	0.1		
carb								
Q/QPK	2%	28%	26%		0%	0%	4%	8%
P/PK	93%	73%	73%		70%	85%	73%	78%
Cl	25.7	10.8	5.4		48.8	51.9	31.9	30.9
hb/hb+bt+cl	77%	79%	74%		100%	99%	95%	89%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Miscellaneous Intrusions

Unit						
Samples	7031	7069	7070	7089	7114	7115
qtz	15.2	18.2	4.8	16.9	12.7	20.9
kfeld	13.6	11.3	9.5	5.3	26.4	19.3
plag	51.4	57.0	53.7	66.8	51.9	41.3
pyx						
hbl	17.9	1.4	24.1			4.0
biot	1.1	10.1	7.4	4.9	6.9	13.5
epid		0.4	0.3	0.1	0.1	0.7
mt	0.5	1.2			0.6	
chl				3.8	0.6	tr
sph	0.3	0.4	0.2	0.1	0.2	0.3
apat	tr	tr	tr	tr	tr	tr
zlr	tr	tr	tr			
musc				2.1		
sulph		tr	tr		0.5	tr
carb					0.1	
Q/QPK	19%	21%	7%	19%	14%	26%
P/PK	79%	83%	85%	93%	66%	68%
Cl	19.0	11.9	31.8	8.8	7.6	18.2
hb/hb+bt+cl	94%	12%	77%	0%	0%	23%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Unit	Black-Pic Batholith										Black-Pic Batholith					
	Foliated to Gneissic Phases (7209 with potassic alteration)										Massive to Foliated Phases					
Samples	7053	7146	7147B	7148	7170	7213	7315	7209	7149	7150	7188	7210	7211	7318	7320	7323
qtz	25.4	28.1	23.1	19.7	21.8	28.2	23.3	22.7	22.6	9.8	2.4	6.8	2.3	23.4	17.6	18.3
kfeld	8.4	8.4	3.7	13.2	5.5	3.5	9.3	18.9	14.1	15.5	18.3	22.5	12.3	8.1	0.8	9.1
plag	50.7	56.9	65.6	60.6	63.7	56.3	60.4	52.9	57.4	48.9	40.3	45.6	62.4	58.5	60.3	55.6
pyx											0.4					
hbl	14.0	0.2	tr		0.2	1.4		tr		23.9	33.2	19.5	17.5		12.1	12.4
biot	0.5	5.6	6.5	6.0	7.5	8.6	5.9	4.5	4.8	1.1	tr	5.3	tr	9.4	8.4	3.5
epid	0.2	0.2	0.5	0.2	0.3	0.8	0.1	0.1	0.2	0.3	tr	tr	0.4	0.2	0.3	0.1
mt	tr	0.1	tr	0.2	0.1	1.0	0.9	0.1	0.4	tr	0.1	tr	tr	0.1	tr	tr
chl		0.3	0.3		0.8		tr	0.7	0.1	tr	5.1	0.2	5.1	0.1	tr	0.1
sph	0.8	0.2	0.2	0.1	0.1	0.1	tr	0.1	0.4	0.4	0.1	0.1	tr	0.2	0.5	0.9
apat	tr	tr	tr	tr	tr	0.1	tr	tr	tr	0.1	0.1	tr	tr	tr	tr	tr
zir	tr		tr	tr		tr	tr		tr			tr		tr	tr	
musc																
sulph		tr	tr			tr	0.1									
carb																
Q/QPK	30%	30%	25%	21%	24%	32%	25%	24%	24%	13%	4%	9%	3%	26%	22%	22%
P/PK	86%	87%	95%	82%	92%	94%	87%	74%	80%	76%	69%	67%	84%	88%	99%	86%
Cl	14.7	6.3	7.3	6.2	8.8	10.8	6.0	5.3	5.1	25.3	38.3	25.0	23.0	9.7	20.8	16.1
hb/hb+bt+c	97%	3%	0%	0%	2%	14%	0%	0%	0%	96%	87%	78%	77%	0%	59%	78%

Hemlo Area Intermediate to Felsic Intrusions - Modal Data

Pukaskwa Batholith

Unit	Foliated to Oncissic Phases (7253 from sill in greenstone belt at Molson Lake)												Foliated to Massive Phases			Dike
	7141A	7144	7254	7255	7256	7271	7273	7276	7281	7253	7277	7286	7291	7276B		
Samples																
qtz	208	20.0	21.1	15.0	19.4	20.8	25.2	26.7	24.6	18.2	28.9	28.3	22.8	30.8		
kfeld	9.5	8.2	8.2	7.9	10.2	6.3	1.7	4.3	7.3	6.9	0.9	3.5	9.0	26.0		
plag	56.2	62.8	62.2	65.1	62.9	63.4	60.1	55.0	59.1	61.4	57.7	56.7	49.7	42.8		
pyx																
hbl	10.8	5.5	2.5	5.9	5.5					3.5		5.5	15.2			
biot	2.0	2.7	2.5	5.6	1.1	6.9	5.7	11.9	8.0	2.1	10.8	4.5	1.3	0.2		
epid	0.1	0.2	0.2	0.1	0.1	1.2	0.3	1.3	0.2	0.2	1.2	0.1	0.1	tr		
mt	tr	0.1	0.3	tr	0.3	tr	0.4	0.2	0.3	0.7	0.2	0.1	tr	0.1		
chl		0.3	2.6		tr	1.1	6.6	0.6	0.5	6.7	0.3	0.4	1.2	0.1		
sph	0.5	0.2	0.3	0.3	0.4		tr	tr	tr	0.2	tr	0.9	0.7			
apat	0.1	tr	0.1	0.1	0.1	0.2	tr	tr	tr	0.1	tr	tr	tr			
zir	tr	tr	tr	tr	tr	tr		tr	tr	tr	tr	tr	tr			
musc																
sulph																
carb	tr	tr	tr			0.1	tr	tr								
Q/QPK	24%	22%	23%	17%	21%	23%	29%	31%	27%	21%	33%	32%	28%	31%		
P/PK	86%	88%	88%	89%	86%	91%	97%	93%	89%	90%	98%	94%	85%	62%		
Cl	12.9	8.7	7.8	11.6	6.7	9.2	12.6	13.8	8.7	12.5	12.3	10.5	17.8	0.3		
hb/hb+bt+cl	84%	65%	33%	51%	83%	0%	0%	0%	0%	28%	0%	53%	86%	0%		

Geochemistry of Intermediate to Felsic Intrusive Rocks

Cedar Lake Pluton													
Main Phase													
Sample	7004A	7006B	7007	7009	7010	7013	7016	7018A	7033A	7034	7038	7067	7219
SiO ₂	65.65	64.66	62.39	64.19	63.53	64.55	66.86	65.26	63.62	63.19	63.43	62.75	65.39
Al ₂ O ₃	16.96	16.27	16.52	16.13	16.30	15.93	15.74	16.03	16.31	16.60	16.72	16.41	15.88
MnO	0.03	0.05	0.05	0.05	0.05	0.04	0.03	0.04	0.04	0.05	0.04	0.05	0.05
FeO	1.81	1.69	2.37	1.94	2.26	1.90	1.32	1.63	1.91	2.15	2.05	2.37	1.85
Fe ₂ O ₃	1.49	1.63	1.59	1.67	1.52	1.56	1.39	1.42	1.57	1.59	1.57	1.62	1.25
MgO	1.45	1.74	2.04	1.84	1.94	1.76	1.48	1.56	1.64	1.84	1.72	1.99	1.61
CaO	3.23	3.44	4.01	3.69	3.61	3.49	2.58	3.13	3.50	3.72	3.63	3.79	3.12
Na ₂ O	5.49	5.42	5.60	5.22	5.45	5.26	5.42	5.53	5.51	5.38	5.61	5.55	5.33
K ₂ O	2.62	2.51	2.12	2.48	2.44	2.59	2.77	2.67	2.59	2.37	2.17	2.05	2.77
TiO ₂	0.49	0.50	0.54	0.53	0.53	0.48	0.38	0.42	0.47	0.51	0.49	0.58	0.45
P ₂ O ₅	0.14	0.17	0.20	0.19	0.18	0.16	0.12	0.14	0.19	0.18	0.15	0.19	0.14
LOI	0.67	0.84	0.69	0.52	0.50	0.43	0.76	0.41	0.68	0.75	0.77	0.82	0.51
TOTAL	100.23	99.11	98.39	98.66	98.55	98.36	99.01	98.42	98.24	98.57	98.59	98.43	98.55
Mg#	45	50	49	49	49	49	51	49	47	48	47	48	49
A/CNK	0.96	0.91	0.88	0.90	0.90	0.89	0.95	0.91	0.89	0.91	0.92	0.90	0.91
S	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
CO ₂	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.16
H ₂ O-	0.1	0.21	0.17	0.11	0.1	0.08	0.16	0.11	0.12	0.17	0.19	0.14	0.18
H ₂ O+	0.56	0.62	0.67	0.45	0.5	0.37	0.62	0.34	0.59	0.67	0.73	0.83	0.33
Li	26	12	14	23	29	25	23	23	20	19	16	11	24
Cs	1.38	0.94	1.12	1.82	3.04	2.51	2.19	1.62	3.56	2.38	1.07	0.86	1.15
Rb	53	55	45	59	65	64	67	63	70	61	51	41	60
Sr	1205	1593	1436	1467	1374	1297	1167	1392	1210	1359	1293	1362	1207
Ba	1142	1480	1335	1351	1256	1295	1243	1465	1044	1271	1067	1274	1299
Nb	5.10	5.67	5.00	5.71	5.10	4.80	4.20	4.60	4.50	4.30	4.60	4.90	6.07
Zr	151	156	170	153	159	149	140	148	145	159	154	167	136
Ta	0.32	0.42	0.29	0.38	0.28	0.27	0.23	0.26	0.26	0.24	0.26	0.27	0.34
Th	4.06	6.82	5.15	5.98	5.24	5.45	5.74	5.06	4.41	4.34	4.08	5.20	5.88
U	0.58	0.67	0.78	1.01	0.83	1.27	1.05	0.66	0.67	0.75	0.65	0.60	0.55
Sc	3	5.42	6	6.16	6	5	4	4	4	6	5	6	5.49
V	51	57	69	65	67	62	47	52	63	67	64	68	55
Cr	22	36	37	39	38	33	26	30	32	31	34	32	30
Ni	13	23	27	23	26	24	18	20	18	21	19	22	20
Co	7	9	11	10	11	9	8	9	10	10	11	11	8
Cu	<5	5	8	9	11	7	<5	<5	7	10	12	<5	11
Zn	85	88	96	86	95	88	74	85	89	94	96	92	80
Pb	13	15	13	15	18	18	17	18	16	11	13	16	18
Y	5	10.79	9	11.34	9	9	7	8	7	8	7	10	9.94
La	36.3	56.4	50.3	49.6	45.7	42.4	40.6	44.9	33.5	49.1	37.2	52.4	46.8
Ce	76.2	113.9	106.7	107.6	96.7	90.2	84.2	92.7	74.4	98.5	78.7	107.5	95.6
Pr	9.78	14.28	13.80	13.22	12.66	11.74	10.92	11.99	9.63	12.22	10.13	14.27	12.54
Nd	36.84	54.25	52.28	51.06	48.10	44.65	39.84	44.99	36.52	44.94	38.76	53.90	46.67
Sm	6.37	9.06	8.74	8.70	8.24	7.48	6.65	7.43	6.26	7.44	6.69	8.96	7.89
Eu	1.58	2.16	2.09	2.17	2.04	1.87	1.67	1.85	1.58	1.85	1.65	2.13	1.98
Gd	3.99	5.64	5.56	5.60	5.23	4.84	4.15	4.63	4.07	4.79	4.25	5.69	5.24
Tb	0.47	0.65	0.67	0.65	0.62	0.58	0.49	0.55	0.50	0.57	0.50	0.66	0.60
Dy	1.68	2.49	2.65	2.59	2.54	2.36	1.93	2.11	1.89	2.27	1.91	2.70	2.30
Ho	0.23	0.38	0.42	0.40	0.40	0.36	0.29	0.33	0.29	0.35	0.28	0.43	0.36
Er	0.53	0.94	1.02	1.06	0.99	0.92	0.72	0.82	0.67	0.91	0.67	1.06	0.91
Tm	0.06	0.11	0.14	0.13	0.14	0.12	0.09	0.10	0.08	0.12	0.08	0.13	0.12
Yb	0.43	0.78	0.84	0.90	0.84	0.76	0.63	0.67	0.57	0.76	0.53	0.82	0.77
Lu	0.06	0.10	0.12	0.11	0.12	0.11	0.09	0.10	0.08	0.10	0.07	0.12	0.12
Eu/Eu*	0.89	0.86	0.86	0.89	0.89	0.89	0.90	0.90	0.90	0.89	0.88	0.85	0.89
Ce _N /Yb _N	49	41	35	33	32	33	37	38	36	36	41	36	34

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Cedar Lake Pluton											
	Main Phase			Mag Grdr		Diorite					Dike	
Sample	7262	7263	7292	7032	7205	7004B	7008B	7009B	7018B	7033B	7217	7205B
SiO ₂	61.83	64.05	65.85	67.27	65.73	60.30	50.68	58.96	60.80	58.42	54.66	74.58
Al ₂ O ₃	17.14	16.80	15.70	16.63	16.59	15.29	14.74	14.61	14.38	14.52	16.72	13.78
MnO	0.03	0.06	0.04	0.02	0.02	0.09	0.20	0.13	0.08	0.11	0.15	<0.01
FeO	1.54	2.22	1.68	1.30	1.39	3.59	6.57	4.06	2.58	4.12	4.86	0.24
Fe ₂ O ₃	1.34	1.11	1.29	1.34	1.45	2.03	4.21	2.52	1.55	2.35	3.12	0.32
MgO	1.81	2.32	1.53	0.87	0.94	3.46	5.98	4.70	4.27	4.77	3.70	0.05
CaO	2.85	2.65	2.99	2.86	3.06	4.68	7.63	6.05	5.10	5.91	6.04	0.95
Na ₂ O	8.09	6.23	5.25	5.68	5.77	4.56	4.35	4.90	4.08	4.63	4.89	4.61
K ₂ O	0.88	0.71	2.76	2.46	2.60	2.80	1.45	0.92	4.38	1.84	2.82	4.11
TiO ₂	0.48	0.54	0.43	0.42	0.49	0.63	0.90	0.58	0.55	0.73	0.83	0.03
P ₂ O ₅	0.16	0.18	0.13	0.10	0.12	0.30	0.29	0.19	0.36	0.23	0.29	<0.01
LOI	1.69	1.62	0.92	0.40	0.44	0.87	0.67	0.67	0.39	0.85	0.64	0.23
TOTAL	98.02	98.74	98.77	99.50	98.76	98.99	98.39	98.73	98.81	98.94	99.26	98.91
Mg#	54	56	49	38	38	53	51	57	66	58	46	14
A/CNK	0.88	1.06	0.92	0.97	0.93	0.80	0.65	0.73	0.69	0.71	0.76	1.00
S	0.08	0.02	0.01	0.01	0.04	<0.01	0.01	0.01	<0.01	0.01	0.01	<0.01
CO ₂	0.71	<.1	<.1	<0.1	0.1	0.15	<0.1	<0.1	<0.1	<0.1	0.1	<.1
H ₂ O-	0.24	0.23	0.2	0.12	0.14	0.1	0.15	0.17	0.11	0.16	0.17	0.08
H ₂ O+	1.02	1.52	0.76	0.28	0.23	0.92	1.14	0.83	0.49	1.07	0.76	<0.03
Li	9	19	10	36	39	35	25	16	16	21	25	4
Cs	0.28	0.63	0.76	2.02	4.44	1.14	1.07	1.18	0.72	2.72	2.06	3.16
Rb	23	37	65	72	79	50	34	27	73	42	59	130
Sr	844	1007	1224	1087	1131	908	971	1110	1302	859	1019	257
Ba	639	396	1192	1001	1023	974	431	472	1983	867	1117	366
Nb	7.31	4.55	5.89	4.70	5.39	5.70	14.80	4.87	8.40	6.20	9.27	2.80
Zr	226	153	125	151	151	156	162	133	187	150	151	46
Ta	0.50	0.24	0.37	0.26	0.31	0.34	1.10	0.31	0.48	0.37	0.49	0.17
Th	6.78	7.04	7.18	4.25	4.45	4.33	11.00	4.25	8.34	3.12	4.00	2.70
U	1.11	0.75	1.24	1.06	1.12	1.33	1.14	0.60	1.01	0.76	1.80	0.87
Sc	4.92	4.64	4.92	2	2.70	13	15	15.02	8	12	17.71	<1
V	55	58	52	43	47	107	184	113	78	122	152	6
Cr	29	34	35	10	10	103	160	197	146	271	15	10
Ni	21	25	21	7	7	24	66	99	122	75	16	<5
Co	12	8	6	6	<5	16	31	22	19	23	23	<5
Cu	235	26	<5	<5	8	<5	51	20	<5	26	57	<5
Zn	47	77	65	87	88	83	241	163	118	147	117	26
Pb	<7	7	18	19	17	17	13	12	21	13	16	26
Y	11.73	8.86	9.75	5	5.9	17	17	11.55	15	14	24.15	1.17
La	48.6	68.9	42.2	33.0	36.8	38.6	86.2	41.0	78.7	28.6	34.7	3.44
Ce	109.0	137.0	83.5	70.3	78.4	85.2	181.8	81.7	175.7	72.6	70.3	7.42
Pr	13.87	16.33	10.91	8.84	9.75	11.47	22.48	10.32	23.99	10.13	10.04	0.97
Nd	51.80	55.93	40.42	32.49	37.82	45.27	79.55	40.81	91.32	40.13	40.87	3.66
Sm	8.75	7.86	6.81	5.54	6.33	8.45	11.72	7.47	15.07	7.63	8.24	0.68
Eu	2.15	1.95	1.88	1.37	1.60	2.10	2.71	1.60	3.51	2.09	2.26	0.22
Gd	5.83	5.25	4.78	3.37	4.09	6.46	7.89	4.97	9.27	5.52	6.76	0.46
Tb	0.74	0.63	0.56	0.39	0.45	0.87	0.96	0.60	1.07	0.71	0.91	0.04
Dy	2.61	2.00	2.02	1.38	1.49	4.20	4.11	2.55	3.93	3.38	4.64	0.17
Ho	0.44	0.32	0.33	0.18	0.21	0.74	0.70	0.43	0.57	0.58	0.89	0.02
Er	1.11	0.78	0.83	0.39	0.47	2.04	1.87	1.13	1.38	1.51	2.60	0.07
Tm	0.14	0.09	0.10	0.04	0.05	0.28	0.25	0.14	0.17	0.20	0.36	0.00
Yb	0.93	0.68	0.73	0.30	0.34	1.84	1.66	0.97	1.09	1.31	2.46	0.11
Lu	0.13	0.10	0.11	0.04	0.04	0.29	0.25	0.14	0.15	0.20	0.39	0.02
Eu/Eu*	0.87	0.87	0.96	0.90	0.90	0.84	0.81	0.76	0.84	0.94	0.90	1.14
Ce _N /Yb _N	64	126	32	65	64	13	30	23	45	15	8	19

Geochemistry of Intermediate to Felsic Intrusive Rocks

Heron Bay Pluton													
Medium Grained Phases													
Sample	7094	7123	7127	7133	7134	7135	7136	7137	7152	7153	7155	7265	7266
SiO ₂	68.63	65.65	67.36	65.91	67.03	67.08	67.75	67.47	65.46	66.48	64.44	68.63	68.38
Al ₂ O ₃	15.77	16.12	15.79	15.81	15.86	15.93	15.99	15.62	16.17	16.07	15.99	15.58	15.66
MnO	0.02	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.06	0.02	0.02
FeO	1.26	1.61	1.47	1.57	1.37	1.38	1.35	1.32	1.78	1.49	2.15	1.09	1.13
Fe ₂ O ₃	1.30	1.48	1.20	1.59	1.32	1.30	1.31	1.24	1.48	1.33	1.63	1.01	0.90
MgO	1.04	1.49	1.22	1.53	1.20	1.16	1.20	1.13	1.54	1.25	1.78	0.85	0.85
CaO	3.11	3.27	2.97	3.23	3.13	3.17	3.06	2.89	3.51	3.28	3.49	2.68	2.73
Na ₂ O	5.54	5.46	5.17	5.09	5.18	5.28	5.34	5.23	5.16	5.42	5.52	5.36	5.33
K ₂ O	2.05	2.29	2.42	2.24	2.44	2.42	2.24	2.57	2.03	2.03	1.82	2.29	2.57
TiO ₂	0.31	0.34	0.33	0.40	0.38	0.37	0.36	0.34	0.44	0.39	0.42	0.31	0.32
P ₂ O ₅	0.05	0.07	0.06	0.08	0.07	0.07	0.06	0.06	0.08	0.08	0.09	0.05	0.04
LOI	0.56	0.59	0.56	1.17	0.53	0.47	0.64	0.45	0.65	0.67	0.90	0.58	0.38
TOTAL	99.79	98.58	98.74	98.83	98.68	98.81	99.49	98.50	98.54	98.68	98.52	98.57	98.44
Mg#	43	47	46	48	46	45	46	45	47	45	47	43	44
A/CNK	0.93	0.93	0.96	0.95	0.94	0.93	0.95	0.94	0.95	0.94	0.92	0.96	0.95
S	<0.01	<0.01	0.01	0.02	0.01	<0.01	<0.01	<0.01	0.02	0.02	0.01	<0.01	<0.01
CO ₂	<0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.16	0.12	<.1	<.1
H ₂ O-	0.09	0.19	0.17	0.2	0.13	0.11	0.14	0.11	0.12	0.12	0.23	0.18	0.11
H ₂ O+	0.33	0.53	0.41	1.05	0.38	0.33	0.5	0.34	0.55	0.45	0.76	0.31	0.19
Li	32	15	19	21	24	27	24	28	24	20	10	20	25
Cs	3.19	2.61	3.54	1	2.92	2.52	2.34	1.75	2.29	2.04	0.76	2.22	2.14
Rb	64	69	81	54	63	67	69	74	55	61	46	61	70
Sr	889	1099	899	781	1069	1030	1019	955	1060	1051	1125	959	974
Ba	984	1098	960	1036	1258	1080	913	938	1038	1002	1070	938	1015
Nb	2.40	2.87	3.37	3.02	3.29	3.28	3.42	3.46	3.65	3.36	3.64	2.60	2.75
Zr	105	95	102	113	109	110	107	106	115	114	112	96	96
Ta	0.13	0.18	0.24	0.21	0.22	0.23	0.22	0.22	0.26	0.22	0.23	0.19	0.21
Th	2.03	2.32	2.91	2.33	2.58	2.40	2.83	2.98	2.73	2.61	2.52	2.18	2.02
U	0.50	0.73	0.69	0.64	0.62	0.54	0.57	0.57	0.80	0.73	0.67	0.56	0.45
Sc	3	5.00	4.00	4.99	3.99	3.72	3.68	30.49	5.40	3.91	6.39	20.49	20.49
V	42	52	50	55	48	46	46	44	60	49	69	34	34
Cr	22	46	30	38	28	29	30	32	41	30	45	15	16
Ni	11	20	10	17	12	13	10	12	16	13	21	8	9
Co	7	9	7	8	7	6	6	5	8	6	8	<5	<5
Cu	<5	9	5	9	7	9	8	8	11	8	15	6	5
Zn	86	85	75	82	82	77	79	89	84	80	82	73	72
Pb	16	18	19	14	15	20	19	21	12	18	13	18	16
Y	3	3.96	4.86	4.92	4.39	4.21	4.22	3.89	6.14	4.47	7.19	3.37	3.37
La	13.8	14.6	17.6	15.8	19.4	15.2	18.2	18.6	19.7	16.7	16.7	17.4	15.8
Ce	28.6	33.7	35.8	34.4	41.2	34.8	37.7	37.4	42.9	37.3	38.8	33.8	33.5
Pr	3.78	4.05	4.57	4.43	5.09	4.43	4.85	4.68	5.40	4.66	5.08	4.72	4.48
Nd	14.18	15.81	17.61	17.41	19.18	17.69	18.99	17.98	21.74	18.51	20.60	17.65	17.16
Sm	2.44	2.91	3.17	3.13	3.44	3.26	3.38	3.28	3.79	3.34	3.68	2.99	3.03
Eu	0.71	0.85	0.86	0.88	0.99	0.92	0.93	0.91	1.07	0.96	1.08	0.98	1.05
Gd	1.66	1.89	2.10	2.16	2.30	2.17	2.25	2.12	2.67	2.27	2.73	2.01	2.01
Tb	0.21	0.23	0.24	0.26	0.26	0.25	0.25	0.24	0.30	0.25	0.32	0.23	0.23
Dy	0.81	0.90	1.02	1.09	1.02	1.03	0.99	0.93	1.34	1.00	1.42	0.75	0.76
Ho	0.12	0.14	0.16	0.17	0.15	0.14	0.14	0.13	0.21	0.15	0.24	0.11	0.11
Er	0.31	0.37	0.42	0.46	0.37	0.36	0.36	0.35	0.52	0.35	0.66	0.25	0.27
Tm	0.04	0.04	0.05	0.05	0.04	0.04	0.03	0.03	0.06	0.04	0.08	0.03	0.03
Yb	0.26	0.34	0.42	0.39	0.34	0.33	0.30	0.30	0.47	0.33	0.59	0.24	0.24
Lu	0.03	0.05	0.06	0.05	0.05	0.04	0.04	0.04	0.07	0.05	0.09	0.04	0.04
Eu/Eu*	1.02	1.04	0.96	0.98	1.01	1.00	0.97	0.99	0.98	1.01	1.00	1.15	1.22
Ce _N /Yb _N	31	28	24	24	34	29	35	35	25	31	18	39	39

Geochemistry of Intermediate to Felsic Intrusive Rocks

Heron Bay Pluton												
Medium Grained Phases				Transitional Phases								
Sample	7267	7268	7329	7097	7099	7117	7154	7156	7157	7158	7159	7269
SiO ₂	66.23	65.52	68.43	68.42	68.64	61.53	65.05	66.04	66.58	65.73	63.07	66.35
Al ₂ O ₃	16.01	16.78	15.71	15.92	16.25	15.80	16.23	15.90	15.74	15.83	15.58	16.05
MnO	0.04	0.04	0.02	0.02	0.02	0.08	0.04	0.03	0.04	0.04	0.07	0.04
FeO	1.62	1.62	1.38	1.12	1.48	2.89	1.73	1.56	1.59	1.74	2.35	1.19
Fe ₂ O ₃	1.26	1.32	1.05	0.94	0.61	2.10	1.62	1.36	1.40	1.35	1.69	1.70
MgO	1.38	1.51	0.99	0.93	0.95	3.23	1.60	1.37	1.30	1.54	2.78	1.36
CaO	3.16	3.30	2.98	2.40	2.84	4.81	3.76	3.26	3.02	3.11	3.99	3.40
Na ₂ O	5.51	5.40	5.52	5.82	5.60	4.61	5.26	5.38	5.39	5.36	4.96	5.52
K ₂ O	2.34	2.14	1.96	2.22	1.88	1.62	1.63	2.08	2.27	2.35	2.49	1.39
TiO ₂	0.31	0.34	0.39	0.31	0.32	0.51	0.44	0.39	0.33	0.34	0.39	0.38
P ₂ O ₅	0.06	0.06	0.08	0.05	0.02	0.08	0.09	0.06	0.06	0.06	0.10	0.06
LOI	0.43	0.69	0.55	0.86	0.65	1.30	0.90	0.70	0.74	0.73	0.88	1.12
TOTAL	98.53	98.90	99.20	99.13	99.39	98.88	98.53	98.30	98.63	98.37	98.61	98.69
Mg#	47	49	43	46	46	55	47	47	45	48	56	47
A/CNK	0.92	0.98	0.95	0.97	0.99	0.87	0.94	0.93	0.94	0.93	0.86	0.96
S	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01
CO ₂	<.1	<.1	<.1	<0.1	<0.1	<.1	0.27	0.14	<.1	0.14	0.14	<.1
H ₂ O-	0.11	0.16	0.14	0.15	0.08	0.18	0.2	0.13	0.16	0.18	0.18	0.23
H ₂ O+	0.29	0.57	0.36	0.71	0.41	1.37	0.71	0.52	0.57	0.54	0.75	0.93
Li	27	15	26	13	32	19	21	17	16	22	21	20
Cs	3.11	1.21	0.76	0.7	1.43	1.03	1.77	1.62	1.01	1.79	2.52	0.97
Rb	75	56	54	57	51	43	47	51	59	69	78	27
Sr	974	995	1131	849	981	885	1144	1095	1071	1094	1072	1057
Ba	931	1104	902	905	920	753	877	1018	1268	1076	1086	949
Nb	3.29	3.45	2.79	2.20	1.90	3.26	3.66	3.63	3.39	3.03	3.59	4.05
Zr	90	95	110	104	108	108	119	114	100	97	104	111
Ta	0.20	0.23	0.21	0.13	0.11	0.21	0.24	0.24	0.21	0.18	0.21	0.29
Th	2.47	2.35	2.31	2.24	1.82	2.96	2.48	2.90	2.42	2.27	2.55	2.95
U	0.47	0.58	0.62	0.58	0.46	0.55	0.59	0.60	0.70	0.51	0.60	0.87
Sc	4.30	40.49	3.11	2	2	10.91	5.33	4.07	40.49	4.90	9.17	3.95
V	52	55	43	34	38	96	61	52	54	60	79	50
Cr	49	47	18	18	15	132	42	40	34	45	114	38
Ni	15	17	12	8	9	44	16	15	13	17	37	15
Co	8	8	<5	<5	6	17	8	6	7	8	12	8
Cu	8	9	10	11	<5	18	13	14	16	10	11	8
Zn	78	81	85	65	80	88	85	84	76	84	77	87
Pb	17	14	16	14	14	14	12	19	13	17	14	18
Y	4.17	4.43	3.67	3	3	8.53	6.28	4.44	5.06	4.52	8.54	4.59
La	17.2	16.3	17.7	14.1	14.0	18.9	19.3	18.5	15.6	15.6	17.9	19.4
Ce	34.1	33.8	37.2	29.3	30.2	40.1	42.0	39.4	33.3	33.0	40.3	40.6
Pr	4.47	4.54	4.74	3.91	3.94	5.17	5.34	5.02	4.28	4.21	5.15	5.42
Nd	16.48	17.17	18.68	15.09	15.16	20.50	21.25	19.58	17.16	16.72	20.78	20.32
Sm	2.95	3.13	3.36	2.57	2.58	3.69	3.84	3.40	3.07	2.91	3.83	3.61
Eu	0.96	1.05	1.08	0.75	0.75	1.01	1.07	0.96	0.95	0.89	1.11	1.12
Gd	2.04	2.15	2.32	1.65	1.67	2.66	2.69	2.33	2.13	2.02	2.82	2.55
Tb	0.25	0.26	0.24	0.18	0.18	0.34	0.31	0.26	0.25	0.23	0.36	0.30
Dy	0.90	0.98	0.83	0.68	0.71	1.69	1.34	0.98	1.02	0.92	1.64	1.07
Ho	0.14	0.15	0.11	0.10	0.10	0.30	0.21	0.14	0.17	0.14	0.29	0.16
Er	0.37	0.39	0.29	0.24	0.25	0.86	0.54	0.37	0.44	0.39	0.80	0.38
Tm	0.04	0.05	0.02	0.03	0.03	0.11	0.07	0.04	0.05	0.04	0.10	0.04
Yb	0.34	0.37	0.24	0.20	0.21	0.78	0.47	0.30	0.41	0.34	0.78	0.34
Lu	0.06	0.06	0.04	0.03	0.03	0.12	0.07	0.05	0.06	0.05	0.12	0.05
Eu/Eu*	1.13	1.17	1.12	1.04	1.03	0.94	0.97	0.99	1.08	1.06	0.99	1.07
Ce _N /Yb _N	28	25	43	41	40	14	25	36	23	27	14	33

	Heron Bay Pluton								
	Plagioclase Sub-porphyritic Phase								Dike
Sample	7071	7072	7096	7118	7119	7128	7151	7264	7122
SiO ₂	67.52	65.80	66.84	63.62	62.60	68.68	65.62	68.75	66.31
Al ₂ O ₃	16.03	16.05	16.62	15.46	15.58	15.53	15.83	15.45	15.99
MnO	0.03	0.03	0.02	0.07	0.08	0.02	0.03	0.02	0.03
FeO	1.32	1.38	1.23	2.45	2.83	1.07	1.61	1.26	1.39
Fe ₂ O ₃	1.19	1.35	1.18	1.56	1.66	1.04	1.38	1.04	1.42
MgO	1.03	1.11	1.04	2.83	2.89	0.85	1.38	0.88	1.14
CaO	2.75	3.36	2.94	3.84	4.33	2.65	3.42	2.88	3.04
Na ₂ O	5.42	5.84	5.79	5.10	5.10	5.49	5.39	5.51	5.28
K ₂ O	2.46	2.24	1.85	2.22	2.14	2.29	2.03	2.00	2.43
TiO ₂	0.36	0.38	0.34	0.40	0.44	0.27	0.42	0.46	0.39
P ₂ O ₅	0.07	0.08	0.07	0.09	0.11	0.04	0.08	0.09	0.07
LOI	0.83	0.69	0.70	1.08	0.77	0.51	0.62	0.47	0.73
TOTAL	99.15	98.46	98.77	98.99	98.84	98.56	97.99	98.96	98.37
Mg#	43	43	45	57	54	43	46	42	43
A/CNK	0.97	0.88	0.99	0.87	0.84	0.95	0.92	0.94	0.95
S	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01
CO ₂	<0.1	0.16	<0.1	<.1	<.1	<.1	<.1	<.1	<.1
H ₂ O-	0.16	0.13	0.16	0.22	0.14	0.12	0.11	0.15	0.18
H ₂ O+	0.69	0.43	0.52	1.02	0.78	0.37	0.54	0.35	0.54
Li	9	23	16	12	13	14	17	15	22
Cs	0.73	0.51	1.46	0.7	0.64	0.81	1.28	1.29	1.74
Rb	60	47	41	51	48	65	49	58	60
Sr	1068	1232	1161	909	1132	999	1140	883	1047
Ba	1086	1098	1130	1011	1057	890	1034	872	1205
Nb	2.50	2.30	2.20	3.41	4.43	2.11	4.18	3.64	2.98
Zr	115	121	124	103	112	84	118	135	110
Ta	0.13	0.13	0.12	0.21	0.24	0.15	0.30	0.26	0.19
Th	4.08	3.47	2.78	3.00	3.57	1.52	2.82	3.21	2.39
U	1.23	0.59	0.64	0.73	0.92	0.55	0.64	0.90	0.68
Sc	4	4	3	9.00	10.00	3.00	4.33	2.66	4.00
V	46	45	43	74	78	40	56	39	40
Cr	13	14	13	117	107	21	41	19	25
Ni	8	8	9	40	30	10	15	9	10
Co	6	7	6	10	10	6	7	<5	7
Cu	<5	<5	<5	10	20	<5	10	<5	9
Zn	78	87	85	76	84	69	98	81	73
Pb	21	19	20	14	15	19	16	17	18
Y	4	4	4	8.3	9.58	2.98	4.72	4.32	4.27
La	21.8	23.9	21.8	19.0	25.2	9.66	19.0	23.4	17.9
Ce	45.8	49.3	44.8	41.8	50.0	20.5	40.9	47.2	38.7
Pr	6.04	6.45	5.91	5.34	6.38	2.59	5.11	6.67	4.76
Nd	22.45	24.77	22.37	20.90	25.08	10.23	20.67	25.68	18.40
Sm	3.90	4.19	3.88	3.87	4.46	1.92	3.75	4.49	3.40
Eu	1.05	1.12	1.05	1.08	1.20	0.59	1.23	1.29	0.92
Gd	2.47	2.67	2.36	2.82	3.27	1.31	2.74	2.93	2.10
Tb	0.28	0.30	0.28	0.34	0.41	0.16	0.30	0.35	0.24
Dy	1.06	1.16	1.01	1.67	1.92	0.64	1.08	1.05	0.98
Ho	0.17	0.17	0.14	0.29	0.34	0.09	0.14	0.14	0.14
Er	0.40	0.43	0.36	0.82	0.92	0.28	0.38	0.32	0.38
Tm	0.05	0.05	0.05	0.11	0.13	0.03	0.03	0.03	0.04
Yb	0.35	0.36	0.30	0.78	0.90	0.26	0.33	0.27	0.33
Lu	0.05	0.05	0.04	0.12	0.13	0.04	0.04	0.04	0.05
Eu/Eu*	0.97	0.96	0.98	0.95	0.92	1.08	1.12	1.02	0.98
Ce _N /Yb _N	36	38	42	15	15	22	34	49	33

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Gowan Lake Pluton															
	Equigranular Phases								Microcline Megacrystic Phases							
Sample	7181	7183	7184	7230	7231	7243	7250	7252	7160	7173	7175	7233	7234	7235	7236	7237
SiO ₂	61.10	60.18	59.48	60.58	61.20	61.14	61.86	60.36	60.26	58.10	54.69	60.45	56.86	58.99	62.70	62.28
Al ₂ O ₃	16.12	16.12	16.18	16.42	16.31	16.00	15.75	15.65	15.61	16.65	16.85	16.21	17.72	16.19	15.31	15.50
MnO	0.09	0.09	0.10	0.10	0.08	0.09	0.08	0.10	0.09	0.09	0.13	0.09	0.11	0.10	0.09	0.08
FeO	3.03	3.15	3.60	2.68	2.57	2.82	2.65	3.15	3.09	3.18	4.64	2.95	3.54	3.40	2.53	2.63
Fe ₂ O ₃	2.44	2.48	2.38	2.53	2.25	2.23	2.20	2.21	2.35	2.47	2.67	2.06	2.58	2.50	2.31	2.20
MgO	2.58	2.65	2.97	2.29	2.15	2.34	2.27	2.88	2.83	2.94	4.17	2.70	3.25	3.12	2.58	2.61
CaO	4.31	4.39	4.94	3.91	3.63	3.95	3.56	4.31	4.31	3.78	5.06	4.14	5.46	4.58	3.52	3.68
Na ₂ O	4.37	4.58	4.42	5.11	4.97	4.74	4.81	4.69	4.72	4.89	5.16	4.54	5.42	4.61	4.26	4.17
K ₂ O	3.42	3.50	2.80	3.36	3.81	3.51	3.66	3.70	3.07	3.92	2.72	3.43	1.56	3.01	3.58	3.69
TiO ₂	0.57	0.60	0.61	0.57	0.52	0.54	0.52	0.55	0.57	0.58	0.77	0.52	0.64	0.60	0.50	0.51
P ₂ O ₅	0.24	0.24	0.27	0.30	0.25	0.26	0.24	0.30	0.21	0.25	0.32	0.20	0.25	0.23	0.18	0.18
LOI	0.50	0.47	0.65	0.73	0.52	0.49	0.66	0.44	1.20	1.11	1.65	0.77	1.21	0.78	1.19	1.17
TOTAL	99.12	98.80	98.80	98.88	98.56	98.42	98.56	98.69	98.65	98.31	99.35	98.38	98.98	98.50	99.02	99.00
Mg#	47	47	48	45	45	46	47	50	49	49	51	50	50	50	50	50
A/CNK	0.86	0.84	0.84	0.86	0.86	0.85	0.86	0.80	0.82	0.87	0.82	0.87	0.86	0.84	0.89	0.88
S	0.01	0.02	0.01	0.01	0.01	0.01	<0.01	<0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	<0.01
CO ₂	0.11	0.14	<1	0.1	0.14	<1	<1	0.1	0.18	<1	0.32	0.16	0.11	0.18	0.16	0.15
H ₂ O-	0.13	0.14	0.15	0.18	0.17	0.14	0.17	0.12	0.19	0.19	0.2	0.16	0.19	0.14	0.21	0.23
H ₂ O+	0.51	0.44	0.68	0.65	0.42	0.44	0.61	0.47	1.21	1.17	1.61	0.71	1.26	0.79	1.14	1
Li	20	24	17	20	30	22	19	23	14	15	16	21	25	31	21	27
Cs	2.32	2.78	2.34	1.84	4.14	2.86	1.38	1.72	1.16	1.27	0.69	2.78	2.06	3.64	1.37	2.17
Rb	101	94	75	82	112	84	88	109	89	133	72	78	46	85	104	94
Sr	985	1020	1159	1255	1095	982	882	1191	853	1065	796	991	1244	961	767	794
Ba	1243	1287	1117	1488	1421	1336	1261	1405	1275	1729	1470	1453	1008	1353	1180	1226
Nb	8.14	7.91	7.11	8.44	8.81	9.11	8.63	9.96	8.27	8.18	8.59	7.05	7.81	7.78	8.45	8.78
Zr	171	180	177	194	193	170	210	196	169	185	199	159	170	168	155	151
Ta	0.39	0.46	0.35	0.41	0.50	0.67	0.57	0.53	0.69	0.45	0.43	0.44	0.57	0.43	0.66	0.73
Th	6.77	5.09	6.22	6.05	9.74	8.76	8.70	11.18	7.14	4.84	2.62	5.36	5.41	5.30	7.86	6.58
U	0.72	0.79	0.93	1.21	1.46	1.51	0.79	0.78	1.56	0.80	0.83	1.26	1.00	1.31	1.34	1.03
Sc	10.65	100.49	11.65	9.30	7.81	8.92	80.49	9.79	11.39	10.65	15.40	9.71	11.76	11.61	9.34	9.09
V	94	99	108	86	76	81	77	87	100	94	134	87	106	104	82	82
Cr	23	21	28	24	23	25	25	43	58	55	76	53	65	63	48	51
Ni	14	13	14	11	12	12	13	18	20	19	26	17	20	21	17	17
Co	11	12	13	9	9	10	11	12	13	13	17	12	14	16	12	11
Cu	12	12	15	14	19	9	17	13	20	16	20	16	17	16	16	13
Zn	84	84	90	89	86	80	78	83	78	95	107	73	88	85	70	70
Pb	18	21	18	18	25	21	19	20	17	14	10	16	11	15	16	16
Y	17.71	19.43	19.13	18.23	16.06	16.67	15.17	20.11	18.56	20.7	24.22	16.18	17.52	18.08	15.79	15.85
La	46.1	41.6	42.3	56.0	36.8	44.6	54.8	47.6	36.9	48.8	33.6	37.4	52.9	40.9	43.3	40.1
Ce	93.9	90.0	92.1	113.8	78.9	109.0	123.0	113.0	82.0	100.1	91.7	79.4	102.0	85.8	85.1	83.2
Pr	11.29	11.30	11.50	15.16	10.48	13.16	14.53	13.93	10.54	13.23	13.16	10.62	12.88	11.58	11.02	10.90
Nd	43.32	45.08	45.03	57.92	41.81	50.55	54.09	53.65	41.62	53.17	55.16	40.28	47.54	44.60	40.26	40.34
Sm	7.75	8.22	8.08	10.26	8.06	9.41	9.19	10.05	7.25	9.61	10.38	7.44	8.29	8.32	7.16	7.08
Eu	2.00	2.14	2.12	2.77	2.32	2.48	2.28	2.72	1.86	2.43	2.65	2.03	2.11	2.17	1.86	1.84
Gd	5.99	6.27	6.19	7.50	6.06	7.07	6.76	7.38	5.48	7.00	7.95	5.74	6.39	6.46	5.42	5.48
Tb	0.76	0.81	0.81	0.92	0.77	0.90	0.86	1.00	0.70	0.88	1.03	0.73	0.81	0.83	0.72	0.70
Dy	3.53	3.82	3.80	3.93	3.44	3.93	3.63	4.10	3.35	3.92	4.92	3.38	3.68	3.89	3.27	3.30
Ho	0.65	0.69	0.68	0.68	0.60	0.70	0.63	0.75	0.62	0.71	0.88	0.60	0.67	0.69	0.60	0.61
Er	1.77	1.97	1.87	1.85	1.68	1.86	1.70	1.89	1.73	1.86	2.43	1.75	1.83	1.92	1.70	1.72
Tm	0.24	0.26	0.25	0.23	0.22	0.25	0.23	0.26	0.24	0.25	0.33	0.23	0.25	0.26	0.24	0.24
Yb	1.59	1.74	1.75	1.56	1.48	1.68	1.53	1.66	1.69	1.67	2.16	1.57	1.66	1.77	1.63	1.62
Lu	0.24	0.26	0.26	0.24	0.23	0.25	0.24	0.26	0.25	0.26	0.31	0.24	0.26	0.27	0.25	0.25
Eu/Eu*	0.86	0.88	0.88	0.92	0.97	0.89	0.85	0.92	0.87	0.86	0.86	0.91	0.85	0.87	0.88	0.87
Ce _N /Yb _N	16	14	15	20	15	19	58	33	13	17	12	14	17	13	14	14

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Gowan Lake Pluton			Fourbay Lake Pluton				Cedar Creek Stock					Dike
	Enclaves			Main Phase				Main Phase					
Sample	7233B	7235B	7236B	7238	7239	7240	7241	7294	7295	7296	7297	7298	7297B
SiO ₂	55.35	51.80	58.98	62.15	62.75	60.00	62.05	68.40	69.27	68.75	68.85	67.24	75.16
Al ₂ O ₃	13.23	12.32	13.68	15.76	15.78	16.47	15.79	15.43	15.71	15.78	15.69	15.81	13.43
MnO	0.18	0.19	0.15	0.09	0.08	0.10	0.08	0.02	0.02	0.01	0.02	0.02	<0.01
FeO	5.04	5.20	3.68	2.40	2.31	3.38	2.45	0.99	0.99	0.98	1.03	0.97	0.00
Fe ₂ O ₃	2.53	2.71	2.08	2.35	2.13	2.30	2.31	1.05	1.20	1.12	1.17	1.45	0.51
MgO	5.80	10.13	4.87	2.04	1.92	2.66	1.97	0.75	0.72	0.70	0.74	0.79	0.11
CaO	5.89	8.23	5.08	3.37	3.30	4.46	3.58	2.32	2.47	2.24	2.47	2.47	0.65
Na ₂ O	2.27	2.63	2.53	4.75	4.72	4.51	4.93	5.72	5.71	5.65	5.76	5.80	4.68
K ₂ O	5.93	3.12	6.07	4.05	4.16	3.18	3.60	2.45	2.12	2.49	2.22	2.59	4.22
TiO ₂	0.54	0.62	0.50	0.51	0.50	0.61	0.51	0.35	0.38	0.35	0.39	0.42	0.03
P ₂ O ₅	0.28	0.34	0.22	0.25	0.26	0.26	0.26	0.06	0.08	0.07	0.08	0.11	<0.01
LOI	0.91	0.88	0.53	0.57	0.38	0.45	0.35	0.99	0.53	0.46	0.54	0.63	0.53
TOTAL	98.51	98.74	98.78	98.56	98.55	98.75	98.16	98.64	99.30	98.72	99.08	98.41	99.29
Mg#	59	70	61	45	45	47	44	41	38	39	39	38	30
A/CNK	0.63	0.54	0.69	0.86	0.86	0.87	0.85	0.95	0.97	0.98	0.96	0.94	1.00
S	0.01	0.02	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
CO ₂	0.22	0.16	<.1	0.15	<.1	<.1	<.1	0.42	0.11	<.1	0.12	<.1	0.11
H ₂ O-	0.18	0.2	0.13	0.16	0.12	0.13	0.12	0.18	0.12	0.15	0.19	0.15	0.15
H ₂ O+	1.02	1.38	0.66	0.46	0.28	0.42	0.26	0.28	0.3	0.28	0.24	0.39	0.13
Li	12	34	15	21	23	22	33	29	28	23	32	24	5
Cs	1.33	1.56	1.06	3.37	3.79	2.01	3.33	1.03	0.96	0.88	1.09	1.07	0.95
Rb	91	75	127	107	99	79	109	56	55	60	56	66	113
Sr	679	725	718	996	941	978	1048	1000	1096	1059	1086	1226	143
Ba	2676	1282	1572	1321	1348	1377	1365	870	857	1014	782	966	129
Nb	8.23	22.09	10.03	9.43	8.96	8.23	11.34	3.64	3.79	3.53	3.79	4.73	2.99
Zr	137	147	139	181	192	170	185	125	128	121	134	138	40
Ta	0.32	0.89	0.73	0.58	0.71	0.81	1.77	0.26	0.26	0.25	0.27	0.28	0.23
Th	1.36	8.48	3.29	7.98	11.99	5.53	7.70	3.25	3.32	3.15	3.46	4.37	3.62
U	0.45	1.95	0.75	2.27	1.63	0.68	0.90	0.68	0.64	0.64	0.71	0.84	1.07
Sc	15.84	16.43	12.11	8.34	7.34	10.92	7.90	2.30	2.23	2.23	2.24	2.08	<1
V	109	123	87	75	70	101	74	31	34	31	34	38	6
Cr	391	653	213	19	21	22	21	17	13	14	15	12	6
Ni	68	107	44	11	10	12	10	7	6	8	8	7	<5
Co	23	33	18	10	8	12	9	<5	<5	<5	<5	<5	<5
Cu	<5	10	<5	16	<5	10	5	<5	<5	<5	<5	<5	<5
Zn	113	97	93	79	72	84	78	75	78	72	79	96	16
Pb	16	9	18	23	30	21	20	13	13	15	15	14	13
Y	23.43	18.15	18.9	17.84	14.87	17.41	16.87	4.11	4.37	4.11	4.5	4.27	0.78
La	24.6	69.2	29.9	58.4	53.6	45.5	56.2	24.2	26.6	23.5	27.0	35.0	3.03
Ce	72.1	159.0	81.1	136.0	115.0	101.0	123.0	51.1	55.8	49.9	56.9	72.6	6.17
Pr	11.66	20.08	12.19	15.98	13.97	12.62	15.22	6.43	7.07	6.31	7.24	9.15	0.70
Nd	50.44	73.69	47.09	58.44	51.68	48.70	56.69	24.36	26.73	23.85	27.27	34.06	2.31
Sm	10.29	11.62	8.49	10.24	8.80	9.13	9.92	4.18	4.64	4.18	4.77	5.68	0.36
Eu	2.63	2.92	2.21	2.55	2.24	2.47	2.51	1.17	1.29	1.23	1.31	1.50	0.11
Gd	7.94	8.20	6.59	7.48	6.34	7.07	7.20	2.74	3.00	2.83	3.13	3.60	0.22
Tb	1.03	1.01	0.84	0.94	0.79	0.91	0.90	0.31	0.33	0.32	0.35	0.40	0.01
Dy	4.89	4.05	3.80	3.95	3.32	4.06	3.86	0.94	1.05	0.97	1.10	1.10	0.07
Ho	0.90	0.71	0.71	0.71	0.58	0.74	0.68	0.13	0.14	0.13	0.14	0.13	0.00
Er	2.53	1.89	2.01	1.95	1.62	1.98	1.88	0.32	0.33	0.33	0.34	0.28	0.03
Tm	0.35	0.25	0.29	0.26	0.22	0.27	0.25	0.03	0.03	0.03	0.03	0.02	-0.01
Yb	2.34	1.70	1.99	1.76	1.44	1.73	1.69	0.27	0.28	0.27	0.29	0.24	0.07
Lu	0.37	0.26	0.32	0.27	0.22	0.27	0.26	0.04	0.04	0.04	0.04	0.03	0.01
Eu/Eu*	0.86	0.87	0.87	0.85	0.87	0.91	0.87	0.99	0.99	1.03	0.97	0.95	1.11
Ce _N /Yb _N	9	72	11	54	39	21	56	53	55	51	54	84	24

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Dotted Lake Batholith											
	Main Phase											Extern
Sample	7045	7050	7056	7079	7302	7303	7306	7308	7310	7312	7313	7305
SiO ₂	72.66	73.38	74.09	71.39	72.16	69.18	70.66	72.62	71.46	70.60	71.01	68.25
Al ₂ O ₃	15.17	15.19	15.00	15.44	14.57	15.85	15.12	14.55	14.68	15.06	15.10	14.77
MnO	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.06
FeO	0.37	0.47	0.38	0.74	0.98	1.04	1.07	0.71	0.79	1.05	0.84	2.31
Fe ₂ O ₃	0.52	0.42	0.42	0.67	0.50	1.03	0.94	0.73	0.67	0.89	0.78	1.34
MgO	0.27	0.27	0.26	0.46	0.50	0.97	0.80	0.44	0.57	0.74	0.58	1.33
CaO	1.63	1.71	1.73	2.11	1.78	2.96	2.54	2.00	1.28	2.53	2.27	3.47
Na ₂ O	5.96	5.85	6.10	5.70	5.18	5.41	5.20	5.08	5.62	5.19	5.79	4.18
K ₂ O	1.96	1.98	1.49	1.98	2.01	1.16	1.35	1.93	2.07	1.33	1.07	1.48
TiO ₂	0.11	0.11	0.11	0.16	0.16	0.24	0.23	0.16	0.17	0.22	0.22	0.38
P ₂ O ₅	0.02	0.02	0.02	0.02	<0.01	0.02	0.02	<0.01	<0.01	0.02	0.01	0.05
LOI	0.42	0.44	0.38	0.41	0.82	0.85	0.94	0.59	1.06	0.68	0.89	1.09
TOTAL	99.11	99.88	100.00	99.16	98.80	98.86	99.02	98.92	98.49	98.46	98.67	98.97
Mg#	37	36	38	38	38	47	43	36	42	42	40	40
A/CNK	1.02	1.02	1.01	1.01	1.05	1.02	1.03	1.03	1.06	1.03	1.02	1.00
S	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01
CO ₂	<0.1	<0.1	<0.1	<0.1	<1	<1	<1	<1	0.18	<1	0.17	0.29
H ₂ O-	0.13	0.09	0.1	0.12	0.15	0.17	0.23	0.14	0.16	0.15	0.15	0.17
H ₂ O+	0.25	0.21	0.22	0.28	0.61	0.66	0.73	0.36	0.74	0.46	0.62	0.74
Li	31	22	23	60	48	30	27	36	25	33	13	16
Cs	1.77	0.79	0.28	1.91	1.86	1.07	1.1	1.73	1.01	2.71	0.96	1.59
Rb	47	55	29	58	52	38	40	46	53	46	31	54
Sr	741	683	753	400	344	492	432	412	291	444	589	303
Ba	894	804	908	520	545	385	405	619	514	432	519	405
Nb	1.40	1.40	1.40	2.50	2.55	2.19	2.58	1.80	1.86	2.42	1.46	4.57
Zr	59	62	62	68	73	82	85	70	70	82	86	97
Ta	0.09	0.09	0.08	0.22	0.32	0.21	0.27	0.15	0.17	0.21	0.14	0.38
Th	0.60	0.76	0.83	0.85	1.29	0.71	0.97	0.94	1.12	1.10	1.34	2.38
U	0.22	0.28	0.43	0.33	0.39	0.25	0.36	0.33	0.38	0.30	0.41	0.48
Sc	1	<1	<1	2	2.24	3.89	2.84	2.11	2.31	2.77	2.44	6.79
V	8	9	8	15	17	28	25	16	16	26	24	55
Cr	10	12	10	10	16	18	15	12	13	14	20	30
Ni	<5	<5	<5	7	7	17	10	5	6	11	6	18
Co	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	7
Cu	<5	<5	<5	<5	<5	7	8	<5	<5	<5	<5	<5
Zn	35	38	31	43	39	49	47	39	39	46	28	63
Pb	14	11	8	8	<7	9	7	<7	<7	<7	<7	7
Y	<2	<2	<2	4	5.18	4.27	4.18	2.63	3.9	3.49	2.62	8.79
La	4.72	5.71	7.05	6.17	6.97	5.42	4.57	7.11	7.28	9.11	8.25	19.0
Ce	11.2	12.4	14.4	13.2	15.4	11.5	9.6	15.0	15.1	18.0	16.7	36.3
Pr	1.44	1.57	1.79	1.66	1.82	1.54	1.23	1.82	1.83	2.16	1.97	3.97
Nd	5.65	5.78	6.37	6.18	6.66	6.19	4.98	6.66	6.79	7.89	7.33	13.43
Sm	1.15	1.05	1.15	1.29	1.42	1.41	1.21	1.22	1.35	1.44	1.43	2.34
Eu	0.42	0.36	0.41	0.36	0.46	0.53	0.48	0.52	0.48	0.51	0.55	0.74
Gd	0.86	0.69	0.77	1.07	1.25	1.26	1.08	0.93	1.11	1.17	1.08	2.12
Tb	0.10	0.08	0.09	0.15	0.17	0.17	0.14	0.11	0.14	0.14	0.12	0.29
Dy	0.50	0.38	0.43	0.81	0.89	0.80	0.76	0.50	0.69	0.65	0.52	1.53
Ho	0.07	0.06	0.06	0.14	0.16	0.13	0.13	0.08	0.12	0.10	0.07	0.29
Er	0.21	0.17	0.16	0.38	0.48	0.39	0.37	0.21	0.34	0.31	0.20	0.84
Tm	0.02	0.02	0.02	0.06	0.06	0.04	0.04	0.02	0.04	0.03	0.02	0.11
Yb	0.21	0.17	0.18	0.38	0.47	0.34	0.39	0.26	0.35	0.30	0.21	0.85
Lu	0.03	0.03	0.03	0.05	0.07	0.05	0.06	0.04	0.05	0.04	0.03	0.14
Eu/Eu*	1.24	1.21	1.26	0.91	1.03	1.19	1.26	1.43	1.16	1.16	1.30	1.00
Ce _N /Yb _N	15	20	22	10	9	9	7	16	12	17	22	12

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Picture Island Stock			Botham Stock				Melgund Stock		
	Main Phase			Med Grained		Fine grained		Main Phase		
Sample	7222	7223	7224	7066	7301	7299	7300	7129	7130	7131
SiO ₂	70.41	71.68	68.55	69.40	70.02	67.40	57.05	60.97	61.23	60.65
Al ₂ O ₃	14.44	14.41	15.00	15.55	15.32	16.16	18.77	15.32	15.36	15.33
MnO	0.04	0.05	0.05	0.01	<0.01	0.02	0.06	0.08	0.08	0.08
FeO	1.15	0.73	1.46	0.61	0.68	1.52	2.27	3.41	3.38	3.50
Fe ₂ O ₃	1.22	1.18	1.39	0.97	0.93	1.15	1.93	1.94	1.91	1.88
MgO	0.89	0.61	1.06	0.58	0.61	1.43	3.28	3.61	3.56	3.67
CaO	2.49	1.88	2.97	2.12	1.74	1.22	2.67	5.40	5.18	5.23
Na ₂ O	4.68	4.59	4.42	6.12	5.70	6.92	7.67	4.42	4.55	4.55
K ₂ O	1.71	3.10	2.24	2.30	2.38	0.44	0.91	1.69	1.65	1.73
TiO ₂	0.29	0.21	0.33	0.24	0.25	0.32	0.52	0.53	0.52	0.52
P ₂ O ₅	0.05	0.03	0.07	0.02	0.05	0.12	0.38	0.08	0.08	0.07
LOI	1.23	1.00	1.09	0.83	0.58	1.55	2.19	0.95	0.92	1.08
TOTAL	98.74	99.54	98.79	98.80	98.35	98.42	97.95	98.77	98.80	98.69
Mg#	41	38	41	41	42	50	59	56	55	56
A/CNK	1.03	1.01	0.99	0.95	1.01	1.15	1.02	0.81	0.82	0.81
S	<0.01	0.04	0.02	0.02	<0.01	0.01	<0.01	0.03	0.02	0.02
CO ₂	<.1	0.18	0.19	0.33	<.1	0.13	0.12	0.34	<.1	0.17
H ₂ O-	0.25	0.19	0.22	0.13	0.15	0.24	0.27	0.15	0.19	0.19
H ₂ O+	0.99	0.69	0.81	0.36	0.36	1.4	2.17	0.83	1.02	1.11
Li	15	13	28	23	16	16	21	20	18	23
Cs	0.78	0.58	1.33	3.14	2.73	0.7	0.16	2.31	1.53	2.12
Rb	33	69	52	67	67	19	25	50	48	51
Sr	478	280	520	1125	1200	982	1957	743	742	756
Ba	721	665	787	951	1013	630	279	736	702	704
Nb	5.77	10.13	6.01	1.80	1.62	4.96	8.65	2.93	3.01	2.98
Zr	102	95	117	117	107	134	170	95	100	102
Ta	0.53	1.01	0.55	0.11	0.13	0.27	0.44	0.23	0.20	0.18
Th	7.00	8.36	6.46	3.15	3.34	8.58	18.45	1.77	2.13	2.05
U	1.11	2.03	1.27	1.02	0.88	1.81	3.55	0.49	0.57	0.82
Sc	3.06	30.49	4.37	2	10.50	3.96	7.88	12.00	12.00	15.00
V	32	25	43	27	28	45	68	110	110	110
Cr	17	14	22	13	14	27	85	174	166	173
Ni	7	6	10	<5	6	23	75	52	54	53
Co	<5	<5	6	<5	<5	8	14	20	20	20
Cu	10	11	13	<5	<5	<5	163	10	8	7
Zn	52	46	60	80	82	57	80	91	93	91
Pb	9	17	12	21	22	12	17	9	15	10
Y	6.85	8.88	7.08	2	2.87	10.08	18.67	8.41	8.48	8.35
La	37.8	22.1	36.2	18.9	21.9	52.6	312.2	14.4	14.9	14.1
Ce	79.7	47.8	74.2	40.5	44.5	123.8	343.8	31.2	31.4	30.6
Pr	9.54	5.92	9.03	5.34	5.63	13.60	36.49	4.06	4.01	3.99
Nd	32.41	20.74	30.94	20.32	21.33	50.88	133.97	16.37	16.23	16.17
Sm	4.82	3.55	4.48	3.63	3.69	8.38	20.44	3.21	3.16	3.19
Eu	1.17	0.83	1.17	0.95	1.15	2.04	4.54	0.93	0.92	0.90
Gd	3.23	2.67	3.08	2.12	2.35	5.63	13.36	2.47	2.46	2.47
Tb	0.40	0.33	0.38	0.22	0.24	0.66	1.51	0.32	0.32	0.32
Dy	1.58	1.61	1.47	0.73	0.66	2.23	4.34	1.68	1.67	1.66
Ho	0.25	0.29	0.26	0.10	0.08	0.34	0.64	0.31	0.29	0.30
Er	0.67	0.82	0.71	0.21	0.20	0.88	1.46	0.86	0.89	0.90
Tm	0.08	0.11	0.08	0.02	0.01	0.11	0.17	0.11	0.11	0.11
Yb	0.60	0.82	0.64	0.17	0.19	0.83	1.25	0.82	0.80	0.80
Lu	0.09	0.12	0.10	0.02	0.02	0.12	0.18	0.12	0.12	0.12
Eu/Eu*	0.85	0.79	0.91	0.96	1.12	0.86	0.79	0.97	0.97	0.94
Ce _N /Yb _N	37	16	32	66	65	41	76	11	11	11

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Musher Lake Pluton					Ogilvie Isl Grdr		Satellite Stock		
	Main Phase					Main Phase		Diorite	Grdr	PorGrdr
Sample	7075	7093	7207	7261	7813	7324	7325	7257	7260	7259
SiO ₂	62.83	62.95	64.78	61.58	63.21	67.46	65.83	55.17	66.04	67.73
Al ₂ O ₃	16.32	16.46	15.87	16.81	15.95	15.36	15.10	13.83	16.32	16.04
MnO	0.06	0.05	0.05	0.06	0.04	0.03	0.04	0.15	0.02	0.02
FeO	2.56	2.13	2.13	2.89	2.36	1.42	1.81	5.16	1.33	0.97
Fe ₂ O ₃	1.76	1.66	1.50	1.64	1.40	1.19	1.03	2.36	1.42	1.33
MgO	2.07	2.07	1.79	2.26	1.89	1.88	1.99	7.03	0.97	0.71
CaO	3.92	2.99	3.47	3.50	3.42	2.87	3.31	7.26	2.76	2.21
Na ₂ O	4.85	5.15	4.65	4.68	4.42	4.80	4.91	3.55	5.80	5.99
K ₂ O	2.43	2.38	2.57	3.26	3.64	2.20	1.88	2.35	2.26	2.79
TiO ₂	0.58	0.49	0.51	0.62	0.52	0.32	0.36	0.76	0.41	0.40
P ₂ O ₅	0.17	0.14	0.15	0.17	0.10	0.06	0.06	0.24	0.10	0.11
LOI	0.66	1.62	1.09	1.37	0.63	1.61	2.19	1.13	0.79	0.39
TOTAL	98.48	98.33	98.79	99.16	98.47	99.36	98.71	99.56	98.38	98.80
Mg#	47	50	48	48	48	57	56	63	40	37
A/CNK	0.92	1.00	0.95	0.96	0.92	0.99	0.94	0.64	0.96	0.95
S	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.02	0.02	0.02	<0.01
CO ₂	<0.1	0.12	0.11	<1	0.06	0.36	1.1	0.12	0.3	0.12
H ₂ O-	0.17	0.27	0.2	0.29	0.1	0.21	0.24	0.24	0.17	0.13
H ₂ O+	0.68	1.45	0.88	1.27	0.49	1.21	1.02	1.4	0.42	0.18
Li	26	26	19	18	25	17	26	22	25	22
Cs	1.9	0.47	1.89	1.82	2.10	1.13	1.87	3.09	2.01	1.96
Rb	58	37	59	95	93	61	58	59	71	82
Sr	1084	788	917	880	1083	658	738	877	1034	1153
Ba	1224	831	1006	1183	1889	689	549	860	915	1057
Nb	5.20	4.60	5.63	7.00	5.53	3.18	3.73	5.12	5.30	6.71
Zr	148	135	130	151	136	117	127	146	134	147
Ta	0.30	0.27	0.37	0.49	0.33	0.31	0.35	0.39	0.35	0.42
Th	3.96	3.15	4.89	4.45	3.97	4.29	4.62	6.98	3.53	4.05
U	0.52	0.79	0.89	0.92	0.66	1.38	1.19	1.77	0.76	0.96
Sc	8	6	60.50	7.62	7	5.01	5.35	17.43	20.50	1.67
V	86	69	68	83	72	47	51	151	43	38
Cr	37	33	34	35	36	67	66	382	18	12
Ni	22	19	17	18	21	43	43	99	9	7
Co	13	10	7	12	9	7	8	27	5	<5
Cu	8	7	10	14	8	16	<5	13	7	<5
Zn	91	76	71	81	90	60	64	100	91	79
Pb	10	12	15	7	18	16	19	14	14	19
Y	10	8	10.86	12.2	12.16	4.78	5.51	18.55	5.11	4.91
La	36.4	25.0	36.3	32.2	35.3	15.7	17.8	41.8	29.5	26.8
Ce	77.1	55.3	78.5	67.7	77.1	32.9	37.5	84.7	60.9	62.8
Pr	10.08	7.36	9.67	9.59	9.61	3.90	4.44	12.25	8.62	8.21
Nd	38.41	28.43	37.30	36.24	38.80	14.95	16.94	47.08	32.59	30.81
Sm	6.59	5.00	6.38	6.65	6.36	2.59	2.90	8.32	5.76	5.88
Eu	1.70	1.31	1.64	1.92	1.30	0.87	0.88	2.19	1.57	1.63
Gd	4.50	3.44	4.52	4.85	3.97	1.95	2.18	6.23	3.70	3.92
Tb	0.56	0.42	0.55	0.64	0.49	0.22	0.25	0.84	0.43	0.47
Dy	2.50	1.88	2.34	2.58	2.49	0.95	1.08	3.62	1.28	1.43
Ho	0.42	0.31	0.38	0.46	0.42	0.16	0.17	0.71	0.18	0.18
Er	1.06	0.81	1.04	1.16	1.15	0.45	0.52	1.87	0.39	0.31
Tm	0.14	0.10	0.13	0.15	0.14	0.05	0.06	0.27	0.04	0.03
Yb	0.89	0.69	0.89	0.97	0.97	0.46	0.48	1.75	0.30	0.23
Lu	0.13	0.10	0.13	0.15	0.14	0.07	0.07	0.28	0.04	0.03
Eu/Eu*	0.90	0.91	0.89	0.99	0.74	1.14	1.03	0.89	0.97	0.98
Ce _N /Yb _N	24	22	25	19	22	20	22	13	56	76

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Terrace Bay Batholith			White River Pluton				Miscellaneous Intrusions				
	Enclave	Granodiorite										
Sample	7171B	7171	7172	7040	7041	7042	7043	7031	7069	7070	7114	7115
SiO ₂	57.52	69.06	67.55	53.08	52.42	58.67	58.46	64.92	66.11	57.66	63.73	62.92
Al ₂ O ₃	16.60	15.02	15.07	14.36	14.95	15.43	14.91	16.30	16.43	17.04	17.62	17.04
MnO	0.12	0.03	0.04	0.18	0.17	0.13	0.11	0.04	0.03	0.11	0.02	0.05
FeO	3.29	0.96	1.13	6.33	6.13	4.03	3.69	1.99	1.58	4.00	1.95	2.61
Fe ₂ O ₃	3.55	1.30	1.58	2.97	3.19	2.44	1.98	1.59	1.32	2.41	0.79	1.09
MgO	3.67	1.17	1.50	6.10	5.87	3.65	3.09	1.48	1.14	3.60	0.66	1.76
CaO	5.42	2.79	3.05	6.11	7.27	5.36	4.92	3.57	2.93	5.28	3.06	3.97
Na ₂ O	5.43	5.00	4.91	4.67	3.89	4.58	5.31	5.71	5.57	4.52	4.86	4.37
K ₂ O	1.37	2.46	2.53	1.54	2.16	2.12	3.08	2.22	2.27	2.57	3.82	3.04
TiO ₂	0.54	0.26	0.32	0.84	0.82	0.66	0.59	0.49	0.49	0.73	0.48	0.56
P ₂ O ₅	0.24	0.06	0.09	0.28	0.34	0.20	0.19	0.10	0.15	0.31	0.11	0.15
LOI	0.92	0.54	0.68	1.90	1.37	1.13	2.56	0.52	0.49	0.11	0.90	0.82
TOTAL	99.04	98.76	98.58	99.06	99.25	98.85	99.29	99.16	98.69	98.79	98.22	98.67
Mg#	50	49	51	55	54	51	50	44	42	51	31	47
A/CNK	0.82	0.94	0.92	0.70	0.68	0.79	0.71	0.89	0.97	0.86	1.00	0.96
S	0.02	0.02	0.01	0.02	0.04	0.02	0.04	<0.01	0.01	0.02	0.1	0.01
CO ₂	0.19	0.2	0.12	<0.1	0.13	<0.1	1.7	0.11	<0.1	<0.1	0.33	0.28
H ₂ O-	0.22	0.15	0.17	0.31	0.16	0.22	0.26	0.14	0.17	0.19	0.16	0.14
H ₂ O+	0.84	0.38	0.5	2.31	1.85	1.33	0.99	0.39	0.35	1.18	0.59	0.57
Li	38	25	20	24	18	18	16	25	16	29	28	40
Cs	1.81	1.63	1.05	0.75	0.83	0.6	3.7	2.09	3.23	12.26	6.14	6.51
Rb	53	75	70	36	69	39	73	58	52	58	100	86
Sr	783	888	955	476	807	924	839	958	1259	1128	1662	1342
Ba	393	860	937	714	843	1139	1294	693	1117	1216	1720	1813
Nb	5.31	5.04	5.46	5.10	4.90	6.00	6.50	3.70	4.20	5.60	7.46	6.06
Zr	149	108	119	130	140	144	126	131	156	149	150	160
Ta	0.35	0.40	0.41	0.27	0.27	0.32	0.33	0.21	0.20	0.28	0.43	0.66
Th	4.10	4.84	5.31	3.34	3.30	3.59	3.65	3.47	2.95	5.29	5.50	3.91
U	1.44	1.23	1.12	0.82	0.53	1.23	1.51	0.89	0.46	1.21	1.39	0.54
Sc	13.67	3.64	40.50	12	19	13	11	5	4	12	2.12	7.34
V	121	37	45	184	183	121	106	71	51	127	33	63
Cr	77	31	39	216	246	117	89	25	8	29	14	35
Ni	54	21	26	50	62	37	32	12	6	23	<5	13
Co	17	<5	6	30	29	20	18	9	7	19	<5	9
Cu	79	<5	<5	19	18	22	21	<5	<5	8	17	<5
Zn	124	45	49	103	107	99	82	100	76	94	90	83
Pb	12	9	15	8	7	14	14	13	15	15	18	15
Y	15.39	10.35	12.08	17	17	15	13	5	7	17	3.93	10.71
La	31.9	23.0	29.9	28.6	34.6	26.9	26.0	27.5	37.7	41.8	52.2	37.7
Ce	68.6	50.6	64.4	64.5	72.4	60.4	55.6	55.0	83.0	92.0	108.6	82.1
Pr	8.44	6.40	8.00	8.66	9.87	7.90	7.29	7.34	11.02	12.45	12.98	10.35
Nd	33.18	24.36	30.82	33.95	38.89	30.68	27.60	27.81	41.97	48.17	48.01	39.61
Sm	5.52	4.21	5.22	6.71	7.21	5.76	5.13	4.82	6.75	8.54	7.30	7.03
Eu	1.27	1.10	1.35	1.80	1.96	1.64	1.47	1.21	1.68	2.19	1.78	1.82
Gd	4.39	3.05	3.80	5.33	5.54	4.61	4.16	3.06	4.30	6.41	4.03	4.63
Tb	0.55	0.39	0.48	0.74	0.77	0.66	0.58	0.36	0.50	0.82	0.40	0.56
Dy	2.70	1.88	2.25	3.87	3.95	3.38	3.12	1.43	2.00	4.02	1.12	2.40
Ho	0.51	0.34	0.40	0.71	0.71	0.63	0.58	0.22	0.31	0.72	0.12	0.38
Er	1.52	0.99	1.17	1.98	1.96	1.74	1.70	0.54	0.71	1.94	0.28	1.00
Tm	0.21	0.13	0.15	0.27	0.27	0.25	0.23	0.07	0.09	0.28	0.02	0.12
Yb	1.56	0.96	1.10	1.84	1.76	1.62	1.51	0.45	0.55	1.75	0.24	0.82
Lu	0.25	0.15	0.17	0.27	0.26	0.24	0.24	0.06	0.08	0.27	0.03	0.11
Eu/Eu*	0.76	0.90	0.88	0.89	0.91	0.94	0.94	0.90	0.89	0.87	0.91	0.92
Ce _N /Yb _N	12	15	16	10	11	10	10	34	42	15	126	28

Geochemistry of Intermediate to Felsic Intrusive Rocks

Black-Pic Batholith																
Foliated to Gneissic Phases (7209 with potassic alteration)									Massive to Foliated Phases							
Sample	7053	7146	7147B	7148	7170	7213	7315	7209	7149	7150	7188	7210	7211	7318	7320	7323
SiO ₂	66.94	70.91	70.89	70.08	71.20	68.86	71.78	71.31	69.58	63.21	54.41	60.03	56.31	67.72	63.85	66.10
Al ₂ O ₃	15.46	15.76	15.30	16.02	14.92	15.52	14.71	14.92	16.02	15.63	15.00	15.89	15.90	16.00	16.31	15.43
MnO	0.03	<0.01	<0.01	<0.01	0.02	0.04	0.04	0.02	<0.01	0.05	0.13	0.10	0.12	0.03	0.05	0.05
FeO	1.51	0.69	0.89	0.84	1.10	1.57	1.18	0.60	0.74	2.26	5.25	3.61	4.36	1.52	2.59	1.92
Fe ₂ O ₃	1.22	0.56	0.66	0.59	0.60	1.45	1.04	0.61	1.05	1.24	2.28	2.17	2.27	1.13	1.43	1.38
MgO	1.51	0.42	0.62	0.50	0.73	0.83	0.56	0.55	0.53	2.87	5.38	3.04	4.56	1.04	2.10	1.95
CaO	3.48	2.28	2.83	2.51	2.45	3.53	2.56	1.96	2.24	4.62	6.54	4.73	4.86	3.21	4.53	3.86
Na ₂ O	5.70	5.82	5.43	5.89	5.46	5.04	5.17	5.25	5.99	5.00	3.71	4.22	4.50	5.63	5.26	5.26
K ₂ O	1.46	1.50	0.90	1.37	1.18	1.01	1.10	2.48	1.79	2.45	3.07	3.10	2.25	1.28	1.02	1.64
TiO ₂	0.35	0.21	0.21	0.24	0.21	0.35	0.22	0.14	0.31	0.37	0.76	0.60	0.61	0.38	0.56	0.42
P ₂ O ₅	0.08	0.02	0.02	0.04	<0.01	0.04	0.02	<0.01	0.05	0.14	0.30	0.21	0.28	0.10	0.11	0.11
LOI	0.62	0.40	0.60	0.44	0.49	0.46	0.40	0.46	0.47	0.46	1.37	0.58	2.19	0.59	0.55	0.47
TOTAL	98.53	98.65	98.46	98.62	98.48	98.86	98.91	98.38	98.86	98.55	98.77	98.68	98.70	98.80	98.64	98.80
Mg#	51	38	43	39	44	34	32	46	36	60	57	49	56	42	49	52
A/CNK	0.89	1.03	1.02	1.02	1.01	0.98	1.03	1.00	1.01	0.81	0.70	0.84	0.85	0.97	0.91	0.88
S	<0.01	0.01	0.03	0.01	0.02	0.04	0.06	<0.01	0.01	0.01	0.01	<0.01	0.02	<0.01	<0.01	<0.01
CO ₂	<0.1	0.13	0.18	0.15	0.17	<1	<1	<1	0.14	<1	0.28	<1	0.41	0.11	<1	<1
H ₂ O-	0.11	0.12	0.11	0.14	0.11	0.14	0.13	0.15	0.14	0.12	0.16	0.14	0.31	0.14	0.15	0.12
H ₂ O+	0.52	0.17	0.33	0.23	0.29	0.26	0.24	0.21	0.23	0.36	1.45	0.64	2.07	0.48	0.46	0.37
Li	11	19	26	22	36	28	27	20	21	21	15	31	20	26	23	32
Cs	0.78	0.9	0.45	1.06	1.56	0.71	2.41	1.33	2.01	1	1.11	4.36	0.69	1.17	1.33	1.91
Rb	36	37	24	37	46	29	46	56	57	51	86	102	76	44	35	56
Sr	910	885	1048	962	414	380	333	729	898	1389	834	862	795	958	860	874
Ba	741	678	794	663	431	378	338	951	527	1261	830	987	892	695	488	651
Nb	2.40	0.96	1.16	0.99	1.97	2.30	3.84	2.38	1.45	3.96	5.71	8.36	7.03	3.37	3.10	4.64
Zr	109	93	83	111	75	124	82	62	108	108	119	141	114	121	118	107
Ta	0.12	0.09	0.05	0.07	0.16	0.16	0.33	0.28	0.09	0.25	0.40	0.68	0.39	0.26	0.20	0.37
Th	2.76	2.08	3.25	2.80	1.09	1.97	2.02	2.64	2.56	4.97	6.78	7.43	3.07	3.50	1.85	5.00
U	0.68	0.20	0.12	0.24	0.27	0.75	0.61	0.59	0.80	1.21	1.51	1.15	0.99	0.29	0.71	0.95
Sc	5	1.17	<1	1.32	2.22	4.17	2.77	2.12	1.49	6.72	16.80	12.63	15.07	3.66	60.50	6.36
V	48	17	19	21	21	38	25	16	23	63	145	110	133	41	73	63
Cr	45	12	14	13	16	14	17	21	13	125	175	46	120	21	51	55
Ni	26	<5	8	<5	12	6	5	11	<5	63	32	14	25	13	33	39
Co	8	<5	<5	<5	<5	6	<5	<5	<5	12	22	12	18	6	10	11
Cu	<5	<5	13	<5	<5	9	25	<5	<5	<5	17	13	9	<5	5	<5
Zn	62	49	42	51	41	64	55	34	66	60	93	84	87	65	71	67
Pb	10	8	<7	9	<7	9	10	10	11	14	14	17	<7	7	<7	11
Y	5	1.48	1.23	1.6	3.01	3.15	3.9	3.36	1.8	7.96	20.36	17.5	17.39	5.95	6.97	8.44
La	25.4	9.59	23.2	16.1	8.73	15.9	10.8	13.7	18.1	40.3	32.3	41.4	33.2	32.1	19.4	26.8
Ce	53.9	21.2	46.0	32.4	17.5	30.2	21.4	25.7	37.4	85.8	70.1	83.4	72.0	66.5	41.5	60.3
Pr	6.92	2.43	5.17	3.74	2.02	3.38	2.51	3.20	4.62	10.37	9.46	11.17	9.60	7.99	5.16	7.49
Nd	26.18	9.17	17.69	13.82	7.38	11.40	8.84	11.67	17.04	39.46	39.47	42.65	37.82	29.08	20.16	29.95
Sm	4.26	1.62	1.98	2.13	1.25	1.67	1.52	2.02	2.49	6.03	7.79	7.60	7.32	4.53	3.74	5.05
Eu	1.21	0.61	0.74	0.68	0.42	0.60	0.55	0.63	0.70	1.57	2.03	1.96	1.91	1.33	1.17	1.36
Gd	2.84	1.01	1.14	1.27	0.93	1.21	1.31	1.44	1.43	3.89	6.35	5.88	5.77	3.24	2.92	3.72
Tb	0.34	0.11	0.11	0.13	0.12	0.14	0.17	0.16	0.14	0.45	0.81	0.74	0.75	0.38	0.36	0.45
Dy	1.35	0.37	0.27	0.41	0.54	0.64	0.74	0.69	0.42	1.67	3.98	3.40	3.55	1.29	1.48	1.73
Ho	0.22	0.04	0.04	0.05	0.10	0.10	0.12	0.11	0.05	0.27	0.72	0.64	0.64	0.21	0.24	0.28
Er	0.60	0.11	0.11	0.11	0.26	0.30	0.33	0.29	0.11	0.71	2.07	1.81	1.80	0.50	0.64	0.79
Tm	0.07	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.01	0.09	0.27	0.23	0.23	0.05	0.07	0.09
Yb	0.50	0.09	0.11	0.10	0.29	0.31	0.30	0.28	0.11	0.65	1.88	1.61	1.59	0.42	0.54	0.69
Lu	0.07	0.01	0.02	0.02	0.05	0.05	0.04	0.04	0.02	0.09	0.29	0.25	0.26	0.06	0.08	0.10
Eu/Eu*	1.00	1.36	1.38	1.17	1.14	1.23	1.16	1.07	1.04	0.93	0.86	0.86	0.87	1.01	1.04	0.92
Ce _N /Yb _N	30	65	116	90	17	27	20	26	94	37	10	14	13	44	21	24

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Black-Pic Batholith						
	Dikes				Volcanic		
Sample	7147C	7149B	7209C	7315B		7147	7317B
SiO ₂	74.40	58.55	58.67	73.95		48.24	53.61
Al ₂ O ₃	13.79	16.95	16.62	13.76		14.93	15.76
MnO	<0.01	0.08	0.11	<0.01		0.23	0.16
FeO	0.24	3.15	3.24	0.32		8.81	5.44
Fe ₂ O ₃	0.32	2.38	2.56	0.44		4.67	2.89
MgO	0.07	2.46	3.31	0.15		6.90	5.58
CaO	1.02	4.84	5.03	1.06		11.88	7.00
Na ₂ O	4.43	4.71	4.37	3.75		1.92	3.70
K ₂ O	4.19	2.24	0.76	5.09		0.32	2.58
TiO ₂	0.05	0.61	0.57	0.06		1.12	0.61
P ₂ O ₅	<0.01	0.21	0.19	<0.01		0.04	0.27
LOI	0.31	1.87	2.77	0.60		0.57	0.71
TOTAL	98.82	98.40	98.56	99.21		100.61	98.92
Mg#	19	45	52	27		49	55
A/CNK	1.01	0.89	0.97	1.01		0.59	0.73
S	0.02	0.14	0.06	<0.01		0.08	0.02
CO ₂	<.1	0.48	0.64	0.23		0.16	<.1
H ₂ O-	0.11	0.22	0.29	0.13		0.1	0.2
H ₂ O+	0.08	1.67	2.42	0.2		1.27	1.13
Li	3	20	39	9		20	34
Cs	0.69	0.74	1.47	1.35		1.46	3.57
Rb	69	71	27	111		6	85
Sr	285	1068	888	218		182	953
Ba	1153	1047	579	541		76	953
Nb	1.25	4.95	4.59	1.64		3.03	6.10
Zr	36	159	128	97		70	122
Ta	0.11	0.27	0.32	0.11		0.22	0.37
Th	1.55	4.27	5.27	22.56		0.27	4.00
U	0.27	0.97	1.25	8.42		0.13	0.92
Sc	1.17	10.13	110.50	<1		38.32	22.68
V	<5	99	108	8		312	175
Cr	10	30	77	11		182	126
Ni	<5	12	51	<5		122	28
Co	<5	12	18	<5		50	23
Cu	6	18	31	<5		117	24
Zn	21	98	91	21		109	86
Pb	17	14	36	34		<7	11
Y	<2	13.69	14.94	2.37		23.78	18.34
La	1.93	34.9	38.6	7.09		3.30	24.4
Ce	6.71	73.6	75.9	14.3		9.03	52.7
Pr	0.63	8.98	10.13	1.63		1.44	7.12
Nd	2.53	35.65	38.41	5.46		7.74	28.52
Sm	0.69	6.27	6.56	0.89		2.64	5.98
Eu	0.47	1.67	1.67	0.49		0.88	1.85
Gd	0.48	4.57	4.72	0.67		3.41	5.17
Tb	0.05	0.56	0.60	0.07		0.59	0.71
Dy	0.24	2.67	2.63	0.35		3.96	3.41
Ho	0.03	0.46	0.50	0.06		0.86	0.66
Er	0.07	1.33	1.41	0.22		2.66	1.87
Tm	0.00	0.17	0.18	0.02		0.38	0.25
Yb	0.10	1.19	1.28	0.33		2.59	1.78
Lu	0.01	0.18	0.21	0.05		0.40	0.28
Eu/Eu*	2.37	0.91	0.87	1.86		0.90	0.99
Ce _N /Yb _N	19	17	16	12		1	8

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Pukaskwa Batholith														
	Foliated to Gneissic Phases										External	Massive to Foliated			Dikes
Sample	7141	7144	7254	7255	7256	7271	7273	7276	7281	7253	7277	7286	7291	7272	7276B
SiO ₂	67.26	69.34	65.56	68.36	71.01	69.89	69.46	68.34	69.97	69.55	70.46	68.68	63.97	66.37	73.70
Al ₂ O ₃	15.98	16.00	15.29	15.73	15.16	15.08	15.76	16.16	15.28	16.21	15.39	15.82	16.02	15.78	14.43
MnO	0.02	0.02	0.06	0.04	0.03	0.04	0.03	0.04	0.04	0.02	0.03	0.04	0.06	0.05	<0.01
FeO	1.38	0.97	2.12	1.26	0.87	1.41	1.79	1.58	1.21	1.01	1.31	1.58	2.13	1.85	0.00
Fe ₂ O ₃	1.04	0.95	2.11	1.01	0.94	1.05	1.32	0.94	1.21	1.00	0.94	1.13	1.45	1.82	0.44
MgO	1.02	0.61	1.94	1.07	0.59	0.85	0.87	0.97	0.65	0.60	0.73	1.10	2.00	1.32	0.05
CaO	3.00	2.84	3.49	2.82	2.22	2.84	3.35	3.18	2.55	2.97	3.08	3.22	4.24	3.23	1.34
Na ₂ O	5.95	6.25	4.63	5.72	5.67	4.98	4.85	4.92	5.41	5.92	5.07	5.90	5.52	4.78	5.17
K ₂ O	1.76	0.75	1.31	1.60	1.93	1.52	0.92	1.49	1.29	0.86	0.82	0.43	1.80	1.05	3.04
TiO ₂	0.38	0.26	0.46	0.29	0.24	0.29	0.38	0.30	0.30	0.27	0.30	0.35	0.46	0.48	0.03
P ₂ O ₅	0.07	0.03	0.10	0.06	0.02	0.03	0.05	0.04	0.04	0.02	0.04	0.05	0.19	0.08	<0.01
LOI	0.46	0.47	1.48	0.42	0.40	0.75	0.74	0.86	0.53	0.55	0.71	0.63	0.57	1.49	0.56
TOTAL	98.47	98.60	98.78	98.52	99.19	98.89	99.72	99.00	98.61	99.10	99.02	99.11	98.65	98.51	98.72
Mg#	44	37	46	47	38	39	34	42	34	36	38	43	51	40	18
A/CNK	0.93	0.98	0.99	0.97	0.98	1.01	1.05	1.04	1.02	1.01	1.04	0.99	0.85	1.06	1.01
S	0.02	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.24	<0.01
CO ₂	<1	0.09	0.11	<1	<1	0.15	0.12	0.25	0.12	<0.1	0.13	<1	0.11	0.21	0.15
H ₂ O-	0.12	0.14	0.3	0.14	0.08	0.19	0.16	0.2	0.15	0.17	0.16	0.14	0.15	0.24	0.13
H ₂ O+	0.25	0.26	1.35	0.23	0.24	0.52	0.62	0.53	0.34	0.36	0.47	0.51	0.45	1.44	0.16
Li	18	17	22	46	33	19	20	24	18	13	20	13	10	17	<3
Cs	2.76	0.72	1.82	4.23	4.82	1.23	0.73	1.17	1.06	0.79	1.32	0.4	0.48	0.81	0.61
Rb	47	28	46	51	56	43	36	51	50	25	39	22	30	49	55
Sr	1065	867	559	846	575	327	414	523	560	781	328	778	1316	403	470
Ba	727	505	878	800	641	521	538	639	447	506	294	400	1385	366	1425
Nb	2.24	3.00	7.72	5.46	3.40	6.11	4.93	3.28	7.04	2.16	4.65	3.46	6.83	8.22	1.53
Zr	106	94	122	104	92	112	151	105	131	101	115	104	159	170	40
Ta	0.17	0.24	0.63	0.62	0.29	0.62	0.34	0.20	0.41	0.22	0.51	0.19	0.51	0.70	0.12
Th	2.15	1.69	6.11	3.69	5.43	3.32	3.81	3.14	3.98	1.53	3.53	2.46	5.30	2.39	0.28
U	0.67	0.58	1.24	1.26	1.01	0.76	0.35	0.74	0.52	0.42	1.09	0.31	0.77	0.71	0.21
Sc	3.03	2.64	7.49	3.47	2.48	30.50	2.65	30.50	2.72	2.48	2.72	4.89	6.29	6.05	<1
V	42	27	68	33	24	30	37	33	25	25	27	43	64	50	<5
Cr	17	13	39	21	11	19	15	17	14	13	15	25	45	25	13
Ni	10	8	23	14	6	11	7	11	6	<5	7	16	25	15	<5
Co	<5	<5	12	5	<5	<5	6	<5	<5	<5	<5	6	10	9	<5
Cu	<5	<5	8	<5	5	13	20	11	<5	<5	<5	<5	30	84	<5
Zn	86	57	55	88	48	58	74	53	78	49	61	62	73	61	11
Pb	17	8	<7	12	14	<7	7	10	10	7	9	8	12	<7	9
Y	3.37	4.11	16.07	9.38	5.3	5.03	3.26	5.3	5.92	3.79	4.3	7.03	13.44	8.07	1.74
La	17.2	11.3	39.9	29.3	22.6	18.5	29.2	20.3	26.5	11.6	17.0	20.2	52.1	16.8	1.81
Ce	35.7	27.6	70.1	49.8	41.2	34.1	52.1	42.8	52.7	24.0	31.0	42.2	120.0	32.6	3.73
Pr	4.65	3.26	10.48	8.05	5.41	3.87	5.76	5.29	6.38	2.99	3.48	5.43	15.91	3.97	0.50
Nd	18.00	12.67	37.43	29.49	18.62	13.01	18.07	18.08	21.62	10.79	11.50	20.03	59.15	14.50	1.93
Sm	3.21	2.29	5.99	4.92	2.96	2.17	2.35	2.77	3.48	1.90	2.00	3.54	9.44	2.74	0.38
Eu	0.84	0.75	1.65	1.39	0.91	0.71	0.86	0.84	0.94	0.66	0.60	1.07	2.36	0.88	0.58
Gd	2.01	1.74	4.79	3.52	2.11	1.70	1.58	1.95	2.53	1.44	1.55	2.65	6.56	2.30	0.29
Tb	0.22	0.20	0.66	0.45	0.27	0.23	0.19	0.26	0.33	0.18	0.21	0.35	0.78	0.33	0.03
Dy	0.79	0.87	2.93	1.76	1.00	0.94	0.65	1.07	1.22	0.73	0.85	1.47	2.80	1.55	0.22
Ho	0.11	0.13	0.60	0.32	0.16	0.16	0.11	0.19	0.20	0.13	0.14	0.25	0.45	0.29	0.04
Er	0.30	0.37	1.55	0.81	0.44	0.44	0.29	0.50	0.50	0.32	0.37	0.64	1.16	0.78	0.17
Tm	0.03	0.04	0.23	0.12	0.06	0.06	0.04	0.07	0.06	0.04	0.05	0.08	0.15	0.10	0.02
Yb	0.25	0.35	1.42	0.80	0.43	0.45	0.28	0.47	0.42	0.32	0.36	0.60	1.02	0.70	0.26
Lu	0.03	0.05	0.22	0.12	0.07	0.07	0.04	0.08	0.06	0.05	0.06	0.09	0.15	0.11	0.05
Eu/Eu*	0.94	1.10	0.91	0.97	1.06	1.09	1.29	1.05	0.92	1.17	1.00	1.02	0.87	1.04	5.13
Ce _N /Yb _N	40	22	14	17	27	21	52	25	35	21	24	20	88	13	4

Moose Lake Porphyry

Sample	7001A	7001B	7087	7100	7102	7109	7812A	7812B
SiO ₂	68.72	70.38	68.85	68.44	67.82	69.33	70.49	69.39
Al ₂ O ₃	15.37	15.39	15.31	15.27	15.08	14.80	15.32	15.02
MnO	0.05	<0.01	0.02	0.04	0.01	<0.01	<0.01	<0.01
FeO	0.80	0.21	0.87	0.79	0.32	0.86	<0.06	0.18
Fe ₂ O ₃	2.66	0.90	0.83	1.38	1.64	0.75	0.56	0.97
MgO	0.34	0.17	1.27	1.95	1.34	1.20	0.27	0.17
CaO	0.24	0.14	2.12	3.44	1.89	2.52	0.39	0.73
Na ₂ O	4.44	3.99	5.55	3.65	6.63	4.48	3.00	5.04
K ₂ O	5.13	6.85	2.51	2.33	1.34	2.24	7.31	5.46
TiO ₂	0.23	0.22	0.22	0.26	0.26	0.21	0.21	0.21
P ₂ O ₅	0.02	0.02	0.02	0.06	0.06	0.05	<0.01	<0.01
LOI	1.12	0.93	1.13	1.75	1.79	1.93	0.87	0.84
TOTAL	99.18	99.20	98.77	99.45	98.23	98.48	99.31	98.86
Mg#	16	23	58	63	57	58	47	22
A/CNK	1.16	1.08	0.98	1.03	0.95	1.03	1.13	0.97
S	0.34	0.39	0.13	0.51	0.96	0.01	0.24	0.62
CO ₂	0.17	<0.1	0.65	0.6	0.79	0.97	0.05	0.26
H ₂ O-	0.19	0.14	0.13	0.17	0.1	0.15	0.06	0.09
H ₂ O+	0.7	0.37	0.64	1.01	0.68	0.81	0.43	0.14
Li	37	18	11	22	14	37	37	9
Cs	3.08	2.4	2.16	1.87	1.31	5.58	8.19	2.78
Rb	113	123	56	39	29	58	114	82
Sr	314	343	438	426	504	583	378	704
Ba	1446	2397	1225	745	664	1023	937	1281
Nb	4.00	1.60	5.20	4.60	2.10	4.32	1.59	0.91
Zr	128	125	118	124	124	111	121	116
Ta	0.27	0.10	0.24	0.24	0.12	0.26	0.06	0.05
Th	4.19	4.22	4.01	3.95	4.32	3.81	3.92	3.82
U	1.52	1.48	1.16	1.25	1.54	1.04	1.50	1.18
Sc	2	2	2	3	2	2	1	1
V	27	25	20	30	55	20	20	11
Cr	12	9	18	14	13	13	11	9
Ni	5	<5	11	11	10	6	<5	<5
Co	<5	<5	<5	<5	<5	<5	<5	<5
Cu	<5	<5	<5	7	<5	<5	<5	<5
Zn	60	43	46	53	51	53	21	18
Pb	11	14	18	13	13	12	17	16
Y	5	3	5	6	5	5.34	5.00	4.54
La	28.8	28.0	26.3	28.9	28.3	24.6	25.1	24.9
Ce	60.6	59.0	54.4	58.5	59.0	52.1	54.3	54.1
Pr	7.64	7.50	6.99	7.48	7.63	6.45	6.56	6.51
Nd	28.27	28.08	25.76	28.05	28.63	24.12	25.24	25.28
Sm	5.27	4.78	4.21	4.77	4.71	4.16	4.18	4.01
Eu	1.61	1.22	1.18	1.16	1.21	1.13	1.09	1.04
Gd	3.68	2.65	2.65	3.02	3.06	2.69	2.35	2.17
Tb	0.41	0.29	0.32	0.35	0.35	0.31	0.26	0.24
Dy	1.43	0.99	1.26	1.43	1.35	1.20	1.20	1.09
Ho	0.20	0.13	0.19	0.23	0.21	0.17	0.17	0.16
Er	0.51	0.32	0.47	0.56	0.53	0.48	0.45	0.46
Tm	0.06	0.04	0.06	0.08	0.07	0.05	0.05	0.05
Yb	0.46	0.30	0.43	0.52	0.49	0.41	0.32	0.41
Lu	0.07	0.04	0.06	0.08	0.07	0.06	0.05	0.05
Eu/Eu*	1.06	0.95	1.01	0.87	0.91	0.97	0.97	0.98
Ce _N /Yb _N	37	55	35	31	33	35	47	37

Geochemistry of Intermediate to Felsic Intrusive Rocks

	Hemlo Deposit Area Dikes												
	Feldspar Porphyry								Popcorn Porph		QFP Dike		Aphyric
Sample	7063A	7064	7065	7086	7088	7091	7108	7110	7063B	7090	7085	7103	7089
SiO ₂	60.71	61.48	68.91	60.64	65.32	66.54	69.30	67.64	65.38	63.18	69.28	69.99	69.31
Al ₂ O ₃	16.43	15.92	15.20	16.78	15.52	16.06	15.43	15.49	16.03	16.17	15.50	16.22	15.78
MnO	0.04	0.67	0.02	0.05	0.04	0.02	0.02	0.02	0.02	0.05	0.02	0.02	0.02
FeO	2.75	2.77	0.89	3.03	2.08	1.21	0.86	1.30	1.60	2.42	0.99	0.81	1.09
Fe ₂ O ₃	2.01	1.53	0.96	1.99	1.47	1.30	0.74	1.05	1.05	1.32	0.85	0.80	0.79
MgO	1.81	2.09	0.79	1.85	1.58	1.06	0.72	1.08	1.14	2.06	0.91	0.71	0.88
CaO	4.33	4.38	2.33	4.28	2.76	2.64	1.91	2.43	3.06	3.89	2.32	2.41	2.22
Na ₂ O	5.29	4.84	6.02	4.50	5.14	5.48	5.08	5.43	5.20	4.89	4.39	7.72	5.77
K ₂ O	2.31	1.95	1.02	2.41	2.28	1.41	3.12	2.48	2.58	1.86	2.33	0.07	1.44
TiO ₂	0.69	0.54	0.25	0.73	0.53	0.38	0.28	0.38	0.43	0.46	0.30	0.25	0.32
P ₂ O ₅	0.21	0.12	0.02	0.17	0.19	0.09	0.07	0.11	0.08	0.10	0.07	0.10	0.09
LOI	2.47	2.24	1.10	2.43	1.40	1.87	1.05	1.43	1.51	2.12	2.10	0.74	1.32
TOTAL	99.36	98.23	97.59	99.20	98.55	98.18	98.67	98.99	98.26	98.79	99.17	99.92	99.15
Mg#	41	47	45	41	45	44	46	46	44	50	48	45	47
A/CNK	0.86	0.88	1.00	0.94	0.97	1.05	1.01	0.97	0.95	0.94	1.11	0.95	1.05
S	0.06	0.16	0.05	0.01	0.03	<0.01	0.06	0.05	0.01	<0.01	0.05	0.3	<0.01
CO ₂	1.78	1.67	0.41	1.39	0.74	0.89	0.36	0.69	0.83	1.09	1.02	0.51	0.4
H ₂ O-	0.13	0.14	0.15	0.18	0.17	0.17	0.08	0.15	0.17	0.18	0.18	0.07	0.14
H ₂ O+	0.81	0.9	0.68	1.04	0.68	0.89	0.61	0.63	0.57	1.01	1.05	0.32	0.83
Li	32	53	17	69	26	21	28	25	25	67	27	8	24
Cs	7.93	8.78	4.37	5.28	3.88	0.86	3.13	2.05	10.74	1.06	3.99	0.55	1.38
Rb	69	61	39	69	60	32	75	59	69	22	69	13	39
Sr	982	1222	1227	1009	1214	1248	1170	1165	1033	873	1279	549	1094
Ba	782	1071	916	811	1348	1358	1282	1238	1009	912	1271	823	1128
Nb	4.00	2.60	2.10	3.90	5.50	1.80	3.24	4.29	2.00	3.40	2.20	1.20	4.00
Zr	152	127	94	152	172	113	136	147	129	123	137	97	140
Ta	0.25	0.15	0.14	0.21	0.22	0.09	0.25	0.29	0.12	0.18	0.13	0.07	0.22
Th	3.93	4.69	2.17	4.27	5.90	3.41	8.40	6.02	3.13	2.13	6.15	1.93	5.82
U	0.74	1.38	0.93	0.81	1.14	1.12	2.20	1.28	1.00	0.85	1.58	0.90	1.37
Sc	5	9	3	5	5	3	2.32	30.49	3	6	3	2	3
V	96	89	32	104	59	47	24	33	53	74	33	29	30
Cr	16	22	22	16	30	10	20	31	12	67	19	17	15
Ni	12	13	8	12	19	8	9	15	8	28	14	<5	10
Co	11	13	<5	13	10	6	<5	7	6	13	<5	<5	<5
Cu	5	10	<5	<5	11	<5	<5	10	<5	9	13	17	12
Zn	120	80	67	125	89	85	53	67	77	84	75	43	55
Pb	14	23	26	13	16	25	23	15	18	16	22	44	14
Y	5	8	4	5	12	4	5.67	7.61	4	6	5	2	5
La	31.9	26.9	14.0	31.3	49.5	22.7	38.8	37.6	23.7	16.1	38.1	12.0	37.9
Ce	67.0	56.4	29.8	67.2	104.3	49.2	78.4	79.4	51.0	36.7	76.7	25.2	73.6
Pr	9.00	7.28	3.86	9.00	13.80	6.57	9.24	9.72	6.59	4.93	9.63	3.24	9.33
Nd	34.82	28.17	14.85	34.66	52.55	25.13	32.70	36.55	24.91	19.25	34.62	12.23	33.58
Sm	6.09	5.04	2.79	6.11	8.70	4.26	5.40	6.05	4.06	3.40	5.56	2.14	5.24
Eu	1.60	1.35	0.82	1.56	2.09	1.10	1.33	1.52	1.09	0.91	1.42	0.62	1.33
Gd	3.90	3.47	1.94	3.89	5.68	2.41	3.29	3.94	2.66	2.25	3.35	1.39	3.25
Tb	0.45	0.44	0.24	0.44	0.70	0.27	0.36	0.45	0.30	0.28	0.38	0.16	0.37
Dy	1.68	2.08	0.97	1.60	2.88	0.92	1.25	1.75	1.14	1.20	1.29	0.66	1.41
Ho	0.23	0.36	0.15	0.21	0.48	0.14	0.18	0.27	0.17	0.19	0.19	0.10	0.22
Er	0.52	0.96	0.40	0.48	1.23	0.32	0.48	0.68	0.39	0.50	0.46	0.23	0.54
Tm	0.06	0.14	0.05	0.05	0.17	0.04	0.05	0.08	0.04	0.07	0.06	0.03	0.07
Yb	0.38	0.92	0.35	0.35	1.09	0.25	0.39	0.59	0.32	0.46	0.41	0.19	0.47
Lu	0.05	0.14	0.05	0.05	0.16	0.03	0.05	0.08	0.04	0.06	0.05	0.03	0.07
Eu/Eu*	0.94	0.93	1.02	0.91	0.85	0.96	0.89	0.89	0.95	0.95	0.93	1.03	0.92
Ce _N /Yb _N	49	17	24	53	27	55	56	37	44	22	52	37	43

Geochemistry of Intermediate to Felsic Intrusive Rocks

Dikes outside immediate Hemlo Deposit Area								
	N Eagle FP	Black R FP	HBP FP	Screamer FP	Lake Sup FP	Puk Bath FP	HeronBay QFP	HeronBay FP
Sample	7092	7138	7156B	7199	7326	7141B	7221	7327
SiO ₂	63.30	64.82	68.51	62.16	67.73	68.16	66.85	67.86
Al ₂ O ₃	15.75	16.37	15.34	14.20	15.36	15.21	15.76	15.01
MnO	0.02	0.05	0.02	0.05	0.03	0.02	0.01	0.02
FeO	2.33	2.08	1.04	2.55	1.30	1.18	0.85	0.86
Fe ₂ O ₃	0.91	1.27	1.13	1.12	1.49	1.06	0.98	1.09
MgO	0.97	1.53	0.81	2.68	1.36	0.83	0.74	0.83
CuO	3.63	3.47	2.46	4.15	3.52	2.49	2.13	2.65
Na ₂ O	7.82	5.49	5.42	5.76	5.67	5.29	9.10	5.74
K ₂ O	0.59	2.18	2.66	0.02	0.44	2.73	0.00	1.22
TiO ₂	0.46	0.43	0.40	0.38	0.32	0.41	0.28	0.40
P ₂ O ₅	0.10	0.08	0.09	0.18	0.03	0.10	0.04	0.10
LOI	3.09	1.10	0.87	5.14	1.36	0.91	1.90	2.90
TOTAL	99.24	99.10	98.88	98.67	98.75	98.52	98.60	98.77
Mg#	35	46	41	57	48	41	43	45
A/CNK	0.78	0.92	0.94	0.83	0.95	0.94	0.84	0.96
S	0.03	0.04	0.04	0.02	<0.01	0.02	0.08	0.05
CO ₂	2.4	0.92	0.3	3.09	0.37	0.53	1.64	1.69
H ₂ O-	0.14	0.11	0.16	0.29	0.16	0.15	0.14	0.22
H ₂ O+	0.65	0.44	0.4	2.15	0.89	0.31	0.27	1.12
Li	20	32	22	27	17	32	9	18
Cs	3.8	3.48	4.34	1.69	0.55	3.41	2.7	1.83
Rb	37	65	67	18	23	66	16	37
Sr	915	882	1122	588	521	1142	279	961
Ba	875	878	1296	463	264	1329	204	1221
Nb	3.30	2.82	3.87	1.78	1.89	4.23	1.15	2.96
Zr	109	110	147	129	88	150	90	145
Ta	0.19	0.17	0.23	0.15	0.18	0.28	0.11	0.21
Th	2.16	2.39	6.22	5.79	1.06	6.32	1.44	6.28
U	0.56	0.81	1.24	2.03	0.36	1.28	0.40	1.46
Sc	3	5.79	2.88	8.40	6.13	2.81	2.86	2.78
V	57	65	33	70	53	34	47	31
Cr	16	23	13	201	49	14	22	14
Ni	10	13	7	44	23	6	8	7
Co	9	8	<5	12	7	<5	<5	<5
Cu	9	32	8	28	6	<5	<5	8
Zn	98	78	70	53	51	72	37	56
Pb	15	16	19	7	<7	16	<7	16
Y	3	6.26	6.53	10.22	4.5	6.79	3.91	6.83
La	16.7	15.8	40.3	30.9	7.12	42.2	11.5	39.2
Ce	36.6	33.9	86.2	68.2	14.6	91.0	24.2	83.9
Pr	4.91	4.36	10.67	8.73	1.78	11.19	3.06	10.16
Nd	19.16	17.05	41.06	34.82	7.21	43.19	11.20	39.49
Sm	3.33	3.04	6.55	6.47	1.46	6.88	1.94	6.40
Eu	0.92	0.88	1.60	1.61	0.51	1.62	0.53	1.75
Gd	2.13	2.17	4.01	4.58	1.34	4.16	1.51	4.35
Tb	0.23	0.28	0.43	0.53	0.17	0.45	0.17	0.48
Dy	0.73	1.26	1.48	2.13	0.84	1.57	0.80	1.51
Ho	0.09	0.22	0.22	0.34	0.15	0.23	0.13	0.21
Er	0.21	0.59	0.52	0.86	0.42	0.53	0.38	0.56
Tm	0.02	0.08	0.06	0.10	0.05	0.06	0.04	0.06
Yb	0.18	0.55	0.41	0.75	0.41	0.48	0.38	0.48
Lu	0.02	0.08	0.07	0.10	0.06	0.07	0.06	0.07
Eu/Eu*	0.99	1.00	0.89	0.86	1.09	0.86	0.91	0.96
Ce _N /Yb _N	56	17	58	25	10	53	18	49

Geochemistry of Intermediate to Felsic Intrusive Rocks

Sample	Miscellaneous Samples		
	Volcanic	Volcanic Clast	Gabbro
7327B	7328	7200	
SiO ₂	59.84	65.91	45.88
Al ₂ O ₃	14.93	16.71	13.85
MnO	0.05	0.02	0.16
FeO	2.56	0.69	8.12
Fe ₂ O ₃	1.83	0.92	4.59
MgO	3.69	0.50	9.59
CaO	3.42	2.55	9.60
Na ₂ O	2.47	8.01	2.44
K ₂ O	2.46	0.18	1.51
TiO ₂	0.64	0.37	1.25
P ₂ O ₅	0.16	0.06	0.18
LOI	6.20	2.63	0.99
TOTAL	98.54	98.63	99.06
Mg#	61	37	58
A/CNK	1.15	0.93	0.60
S	0.53	0.08	0.08
CO ₂	4.35	1.92	<.1
H ₂ O-	0.34	0.23	0.22
H ₂ O+	2.48	0.74	1.54
Li	40	9	20
Cs	3.48	0.63	0.74
Rb	58	14	31
Sr	139	577	445
Ba	396	175	534
Nb	1.82	1.96	4.40
Zr	115	89	69
Ta	0.15	0.18	0.23
Th	2.48	1.02	0.66
U	0.41	0.29	0.25
Sc	7.21	3.99	46.16
V	67	29	344
Cr	60	42	148
Ni	55	13	35
Co	12	<5	42
Cu	<5	33	40
Zn	63	26	101
Pb	<7	8	<7
Y	8.36	4.62	29.57
La	25.2	9.33	12.5
Ce	57.0	20.1	37.2
Pr	7.09	2.52	6.06
Nd	27.51	10.19	30.16
Sm	4.52	1.93	7.44
Eu	1.28	0.63	2.09
Gd	3.45	1.64	6.92
Tb	0.43	0.20	1.01
Dy	1.74	0.93	5.70
Ho	0.29	0.15	1.12
Er	0.81	0.46	3.23
Tm	0.10	0.05	0.44
Yb	0.75	0.42	2.86
Lu	0.11	0.06	0.42
Eu/Eu*	0.95	1.05	0.88
Ce _N /Yb _N	21	13	4

Plagioclase Feldspar Analyses

Appendix C

Plagioclase Feldspar Analyses

This table lists selected individual electron microprobe analyses and the average analysis for samples investigated in detail.

Individual analyses listed include the most An-rich and An-poor typical analyses and, where applicable, a third analysis (indicated by an asterisk) that is compositionally and, in some cases texturally distinct from the typical plagioclase in the sample. The anomalous samples indicated by the asterisk were not used to compute average compositions.

Average analyses for samples are bolded with the number in brackets following the sample number being the number of analyses incorporated in the average

Sample numbers followed by an asterisk (*) were not used to compute the average composition for the sample

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
Cedar Lake Pluton (various phases and adjacent external dike)													
7004A-1pc3	63.05	0.00	22.86	4.24	0.07	9.10	0.21	0.27	0.00	99.79	34%	65%	1%
7004A-2pc3	64.16	0.02	22.06	3.31	0.07	9.76	0.09	0.27	0.03	99.77	27%	72%	0%
7004A-p(13)	63.89	0.02	22.35	3.61	0.07	9.55	0.09	0.26	0.01	99.85	29%	70%	0%
7004B-2pc3	63.53	0.02	22.20	3.74	0.06	9.69	0.18	0.25	0.00	99.68	30%	70%	1%
7004B-3pc2	64.32	0.00	21.78	3.00	0.07	9.93	0.07	0.20	0.00	99.37	25%	75%	0%
7004B-2pr *	67.02	0.00	20.33	1.19	0.02	11.00	0.08	0.11	0.05	99.80	11%	89%	0%
7004B-p(10)	63.88	0.02	22.11	3.45	0.08	9.74	0.13	0.24	0.02	99.65	28%	71%	1%
7018A-1pc	63.65	0.00	22.28	3.88	0.08	9.13	0.30	0.15	0.02	99.48	31%	67%	1%
7018A-2pc2	64.77	0.03	21.60	2.84	0.08	9.89	0.11	0.08	0.02	99.42	24%	76%	1%
7018A-p(10)	64.53	0.02	21.81	3.17	0.10	9.66	0.19	0.10	0.02	99.61	26%	73%	1%

Plagioclase Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
7018B-1pc4	62.46	0.00	23.14	4.55	0.04	8.75	0.18	0.39	0.00	99.52	36%	63%	1%
7018B-4pr	64.69	0.00	21.76	2.82	0.07	10.10	0.17	0.33	0.01	99.94	23%	76%	1%
7018B-1pr *	66.09	0.00	21.00	1.97	0.07	10.51	0.07	0.18	0.02	99.91	17%	83%	0%
7018B-p(13)	64.13	0.02	22.02	3.28	0.05	9.71	0.15	0.35	0.01	99.72	27%	72%	1%
7031-2pc	62.57	0.08	22.38	5.09	0.03	9.13	0.14	0.00	0.00	99.42	38%	62%	1%
7031-3pr	66.13	0.00	21.28	2.23	0.10	10.53	0.10	0.01	0.02	100.39	19%	81%	1%
7031-p(12)	64.83	0.02	21.83	3.27	0.07	9.83	0.08	0.01	0.00	99.94	27%	73%	0%
7032-1pr	63.80	0.01	22.84	4.14	0.12	9.50	0.07	0.01	0.01	100.50	32%	67%	0%
7032-3pc2	65.52	0.06	21.56	2.65	0.05	10.13	0.12	0.00	0.04	100.14	22%	77%	1%
7032-p(9)	64.66	0.03	22.08	3.41	0.08	9.73	0.11	0.01	0.02	100.13	28%	72%	1%
7033A-2pc2	63.79	0.01	22.67	3.94	0.08	9.32	0.09	0.12	0.00	100.01	32%	68%	0%
7033A-3pc	64.58	0.00	22.39	3.43	0.04	9.70	0.05	0.03	0.00	100.21	28%	72%	0%
7033A-p(9)	64.44	0.03	22.51	3.68	0.07	9.57	0.08	0.05	0.02	100.44	30%	70%	0%
7067-1pc2	63.05	0.00	22.41	3.95	0.06	9.37	0.15	0.12	0.05	99.16	32%	68%	1%
7067-2pr	64.38	0.00	21.87	3.11	0.13	9.84	0.04	0.15	0.01	99.52	26%	74%	0%
7067-1pr *	66.08	0.08	20.69	1.03	0.15	10.66	0.57	0.06	0.02	99.32	9%	88%	3%
7067-p(11)	64.06	0.00	22.14	3.43	0.10	9.64	0.11	0.08	0.02	99.58	28%	71%	1%

Heron Bay Pluton

7071-1pc	63.48	0.03	22.51	3.83	0.06	9.53	0.07	0.05	0.04	99.59	31%	69%	0%
7071-1pr	64.78	0.07	21.73	2.73	0.05	10.14	0.06	0.00	0.00	99.56	23%	77%	0%
7071-p(11)	64.19	0.04	22.09	3.31	0.06	9.79	0.08	0.04	0.02	99.61	27%	73%	0%
7096-2pc	63.33	0.01	22.50	4.02	0.05	9.23	0.15	0.08	0.03	99.39	32%	67%	1%
7096-3pc	65.20	0.10	21.61	2.89	0.02	9.82	0.13	0.04	0.05	99.85	24%	75%	1%
7096-p(9)	64.44	0.03	22.04	3.36	0.05	9.61	0.12	0.06	0.02	99.73	28%	72%	1%

Plagioclase Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
7099-1pr	63.41	0.04	22.56	4.12	0.05	9.31	0.12	0.00	0.00	99.60	33%	67%	1%
7099-2pr	64.65	0.00	21.72	3.16	0.08	9.95	0.02	0.00	0.00	99.58	26%	74%	0%
7099-p(6)	64.13	0.02	22.21	3.65	0.07	9.54	0.14	0.02	0.02	99.81	30%	70%	1%
7152-4pc3	61.91	0.00	23.53	4.94	0.04	8.91	0.14	0.21	0.05	99.74	38%	62%	1%
7152-2pr	65.35	0.00	22.08	3.07	0.02	9.87	0.07	0.25	0.03	100.73	25%	74%	0%
7152-p(16)	63.46	0.02	22.79	4.04	0.03	9.43	0.16	0.25	0.01	100.19	32%	67%	1%
Gowan Lake Pluton													
7175-9pr *	65.04	0.00	21.95	2.97	0.06	9.98	0.07	0.25	0.00	100.31	25%	75%	0%
7175-15p	66.71	0.00	20.76	1.37	0.02	10.91	0.05	0.40	0.01	100.22	12%	88%	0%
7175-8pr	68.51	0.06	19.17	0.03	0.05	11.91	0.02	0.10	0.00	99.84	0%	100%	0%
7175-p(24)	67.52	0.02	20.05	0.65	0.05	11.25	0.20	0.14	0.01	99.90	6%	93%	1%
7183-2pc	61.30	0.03	23.71	5.68	0.10	8.40	0.28	0.00	0.00	99.58	42%	57%	1%
7183-3pc	63.21	0.00	22.76	4.34	0.18	8.96	0.23	0.00	0.03	99.71	34%	64%	1%
7183-p(10)	62.49	0.01	23.26	4.92	0.10	8.76	0.24	0.01	0.02	99.83	38%	61%	1%
7233-3pc	61.76	0.00	23.81	5.60	0.09	8.37	0.12	0.14	0.00	99.93	42%	57%	1%
7233-2pc8	64.80	0.00	22.08	3.40	0.08	9.58	0.14	0.00	0.00	100.09	28%	71%	1%
7233-2pc7 *	68.68	0.00	19.79	0.51	0.02	11.37	0.07	0.00	0.00	100.44	5%	95%	0%
7233-p(17)	63.28	0.02	22.92	4.42	0.08	9.01	0.15	0.03	0.02	99.97	35%	64%	1%
7250-1pc	63.92	0.00	22.60	3.75	0.05	9.49	0.18	0.03	0.00	100.02	30%	69%	1%
7250-3pc	66.91	0.00	20.80	1.92	0.08	10.63	0.12	0.00	0.02	100.48	17%	83%	1%
7250-1pr *	68.38	0.00	19.81	0.63	0.05	11.50	0.13	0.00	0.00	100.49	6%	94%	1%
7250-p(12)	64.72	0.02	22.08	3.36	0.10	9.74	0.16	0.02	0.01	100.23	27%	72%	1%

Gowan Lake Pluton

Plagioclase Feldspar Analyses

Analysis SiO₂ TiO₂ Al₂O₃ CaO FeO Na₂O K₂O SrO BaO Total An Ab Or

Fourbay Lake Pluton

7239-2pc4	64.24	0.00	22.09	3.58	0.11	9.57	0.25	0.00	0.01	99.87	29%	70%	1%
7239-3pc3	65.03	0.03	21.65	2.97	0.12	9.76	0.19	0.00	0.01	99.76	25%	74%	1%
7239-3pr *	66.68	0.00	21.07	2.09	0.09	10.72	0.11	0.00	0.01	100.77	18%	82%	1%
7239-p(14)	64.66	0.02	21.92	3.31	0.13	9.62	0.26	0.02	0.03	99.99	27%	72%	1%
7240-1pc	62.78	0.07	23.23	4.91	0.07	8.70	0.24	0.02	0.00	100.01	38%	61%	1%
7240-2pc4	63.48	0.03	22.72	4.33	0.18	8.98	0.32	0.07	0.03	100.13	34%	64%	2%
7240-p(18)	62.97	0.03	23.14	4.70	0.12	8.87	0.23	0.05	0.03	100.12	37%	62%	1%

Cedar Creek Stock

7297-1pc2	63.74	0.00	22.43	3.70	0.07	9.59	0.27	0.37	0.00	100.16	30%	69%	1%
7297-1pr	65.54	0.00	21.28	2.37	0.06	10.64	0.07	0.14	0.02	100.11	20%	80%	0%
7297-p(11)	64.60	0.00	21.97	3.11	0.06	10.07	0.10	0.25	0.01	100.18	25%	74%	0%

Musher Lake Pluton

7075-1pc	59.98	0.00	24.98	7.11	0.00	7.48	0.16	0.10	0.01	99.81	51%	48%	1%
7075-3pr	64.19	0.00	22.22	3.83	0.08	9.51	0.09	0.00	0.02	99.93	31%	69%	0%
7075-p(12)	62.93	0.02	23.05	4.78	0.06	8.87	0.15	0.02	0.02	99.91	37%	62%	1%

Botham Stock

7066-1pr	65.35	0.00	21.46	2.57	0.10	10.13	0.09	0.00	0.00	99.69	22%	78%	0%
7066-1pc2	65.91	0.04	20.85	2.11	0.09	10.53	0.06	0.00	0.00	99.59	18%	82%	0%
7066-p(6)	65.75	0.01	21.11	2.27	0.07	10.40	0.09	0.00	0.03	99.73	19%	80%	0%

Plagioclase Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
Melgund Stock													
7131-3pc6	59.24	0.00	25.69	7.44	0.02	7.26	0.11	0.25	0.03	100.05	53%	47%	0%
7131-3pc10	63.59	0.07	22.71	4.07	0.02	9.20	0.09	0.20	0.03	99.98	33%	67%	0%
7131-2pr *	66.78	0.00	20.76	1.70	0.04	10.54	0.04	0.10	0.00	99.96	15%	85%	0%
7131-p(32)	61.24	0.01	24.30	5.82	0.02	8.20	0.13	0.25	0.02	99.99	44%	56%	1%
Terrace Bay Batholith													
7171-3pc	62.01	0.02	23.67	4.97	0.14	8.33	0.37	0.23	0.12	99.86	39%	59%	2%
7171-3pr	64.03	0.02	22.62	3.72	0.09	9.42	0.08	0.15	0.03	100.17	30%	69%	0%
7171-p(22)	62.93	0.02	23.02	4.41	0.14	8.88	0.26	0.25	0.05	99.96	35%	64%	1%
White River Pluton													
7041-1pc2	61.88	0.12	23.64	5.18	0.09	8.56	0.16	0.12	0.01	99.75	40%	60%	1%
7041-2pc2	62.11	0.00	23.18	4.77	0.08	8.63	0.33	0.14	0.01	99.27	37%	61%	2%
7041-p(9)	62.13	0.02	23.54	4.99	0.11	8.68	0.17	0.18	0.02	99.83	39%	61%	1%
7042-1pc	62.40	0.00	23.51	5.09	0.05	8.73	0.09	0.09	0.00	99.96	39%	61%	0%
7042-3pc2	65.00	0.00	21.83	3.10	0.09	9.94	0.16	0.02	0.05	100.19	25%	74%	1%
7042-p(15)	63.98	0.02	22.51	3.82	0.10	9.48	0.12	0.02	0.02	100.07	31%	69%	1%
7043-1pc2	64.81	0.04	22.09	3.20	0.07	9.75	0.22	0.04	0.01	100.22	26%	73%	1%
7043-2pc2	65.70	0.00	21.48	2.58	0.05	10.05	0.15	0.00	0.00	100.00	22%	77%	1%
7043-3pr *	65.21	0.00	21.66	1.99	0.25	9.72	0.95	0.02	0.05	99.83	18%	78%	5%
7043-p(7)	65.08	0.01	21.79	2.89	0.08	9.84	0.29	0.01	0.01	100.01	24%	74%	1%

Plagioclase Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
Dotted Lake Batholith													
7050-1pc2	63.94	0.07	22.17	3.72	0.05	9.62	0.04	0.00	0.00	99.62	30%	70%	0%
7050-3pc	65.94	0.00	21.29	2.41	0.05	10.41	0.07	0.00	0.04	100.22	20%	79%	0%
7050-p(10)	65.06	0.02	21.64	2.98	0.06	10.05	0.07	0.00	0.01	99.80	24%	76%	0%
7079-1pc	63.14	0.03	22.87	4.65	0.01	9.22	0.07	0.00	0.00	99.98	36%	64%	0%
7079-1pr	65.40	0.03	21.55	2.91	0.00	10.20	0.04	0.00	0.00	100.12	24%	76%	0%
7079-p(5)	64.49	0.03	22.16	3.67	0.02	9.73	0.06	0.00	0.00	100.15	29%	70%	0%
Picture Island Stock													
7224-2pc2	61.44	0.03	24.11	5.82	0.04	8.42	0.09	0.12	0.04	100.12	43%	56%	0%
7224-3pc2	65.84	0.00	21.18	2.21	0.02	10.41	0.07	0.15	0.00	99.90	19%	81%	0%
7224-p(13)	63.86	0.01	22.61	3.87	0.04	9.53	0.07	0.13	0.01	100.14	31%	69%	0%
Ogilvie Island Granodiorite													
7324-2pc2	64.46	0.04	21.95	3.32	0.07	9.84	0.10	0.08	0.03	99.88	27%	72%	0%
7324-3pc	66.68	0.00	20.79	1.56	0.02	10.82	0.21	0.11	0.05	100.24	14%	85%	1%
7324-4pr *	67.92	0.00	19.58	0.47	0.08	11.39	0.08	0.07	0.00	99.59	4%	95%	0%
7324-p(10)	65.27	0.02	21.49	2.60	0.05	10.29	0.14	0.10	0.02	99.98	22%	78%	1%
Pukaskwa Batholith													
7276-3pc4	60.77	0.00	24.48	6.24	0.04	7.92	0.18	0.16	0.00	99.79	46%	53%	1%
7276-4pc2	63.56	0.00	22.73	4.05	0.03	9.32	0.22	0.11	0.01	100.03	32%	67%	1%
7276-p(22)	62.21	0.01	23.46	5.00	0.05	8.74	0.17	0.13	0.01	99.80	38%	61%	1%

Plagioclase Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
7255-3pc3	63.95	0.00	22.21	3.65	0.07	9.49	0.13	0.15	0.01	99.68	30%	70%	1%
7255-1pc4	64.60	0.05	21.98	3.20	0.07	9.85	0.07	0.24	0.02	100.08	26%	73%	0%
7255-p(14)	64.12	0.02	22.13	3.45	0.07	9.64	0.15	0.20	0.01	99.79	28%	71%	1%
Black-Pic Batholith													
7146-4pc2	63.69	0.00	22.16	3.70	0.06	9.25	0.24	0.17	0.01	99.28	30%	69%	1%
7146-3pc3	64.58	0.00	22.21	3.34	0.04	9.65	0.13	0.20	0.05	100.21	27%	72%	1%
7146-p(20)	64.07	0.01	22.18	3.50	0.05	9.52	0.18	0.19	0.02	99.73	29%	70%	1%
7213-5pc2	61.10	0.00	23.85	5.66	0.09	8.33	0.06	0.13	0.02	99.23	43%	57%	0%
7213-3pc4	62.60	0.02	23.22	4.61	0.07	8.67	0.07	0.09	0.00	99.54	36%	63%	0%
7213-p(28)	61.64	0.01	23.66	5.31	0.07	8.48	0.14	0.11	0.01	99.43	41%	59%	1%

Analytical Conditions: 20kV, 15nA, spot size 10 microns.
 Routine: Custom EDS/WDS feldspar routine.
 Correction Procedure: ZAF-4

Appendix D

Potassium Feldspar Analyses

This table lists average electron microprobe analyses for samples investigated in detail.

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
Cedar Lake Pluton (various phases and adjacent external dike)													
7004A-k(6)	64.44	0.01	18.53	0.01	0.05	0.60	15.66	0.19	0.74	100.23	0%	6%	94%
7004B-k(6)	63.93	0.04	18.40	0.02	0.06	0.46	15.79	0.16	0.86	99.71	0%	4%	96%
7018A-k(16)	63.92	0.02	18.42	0.06	0.04	0.68	15.67	0.00	1.34	100.15	1%	6%	93%
7018B-k(9)	64.14	0.02	18.45	0.02	0.04	0.64	15.41	0.25	0.89	99.87	0%	6%	94%
7031-k(9)	64.81	0.02	18.16	0.06	0.06	0.52	16.31	0.00	0.60	100.55	1%	5%	95%
7032-k(8)	64.58	0.02	18.22	0.07	0.03	0.49	16.28	0.00	0.76	100.45	1%	4%	95%
7033A-k(8)	64.62	0.02	18.40	0.10	0.05	0.59	16.11	0.00	0.77	100.65	1%	5%	94%
7067-k(11)	63.79	0.03	18.42	0.06	0.09	0.46	16.07	0.00	1.26	100.18	1%	4%	95%
Heron Bay Pluton													
7071-k(8)	64.16	0.01	18.22	0.06	0.03	0.50	16.25	0.00	0.73	99.97	1%	4%	95%
7096-k(9)	64.29	0.00	18.24	0.06	0.04	0.65	15.93	0.00	1.04	100.25	1%	6%	94%
7099-k(9)	64.33	0.03	18.19	0.04	0.03	0.53	16.13	0.00	0.89	100.17	0%	5%	95%
7152-k(4)	64.57	0.01	18.56	0.02	0.05	0.63	15.82	0.16	0.78	100.59	0%	6%	94%
Gowan Lake Pluton													
7175-k(7)	63.96	0.02	18.43	0.03	0.05	0.65	15.81	0.00	1.36	100.30	0%	6%	94%
7183-k(3)	64.36	0.07	18.34	0.03	0.05	1.10	15.32	0.00	0.89	100.16	0%	10%	90%
7233-k(8)	64.79	0.02	18.36	0.05	0.05	0.81	15.69	0.01	0.69	100.49	1%	7%	92%
7250-k(5)	64.58	0.01	18.33	0.05	0.05	0.51	16.10	0.00	0.66	100.33	1%	5%	95%
Fourbay Lake Pluton													
7239-k(4)	64.58	0.03	18.33	0.05	0.06	0.62	15.95	0.01	0.63	100.27	0%	6%	94%
7240-k(5)	64.20	0.02	18.41	0.08	0.07	0.70	15.66	0.00	1.02	100.16	1%	6%	93%

Potassium Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
Cedar Creek Stock													
7297-k(4)	63.98	0.01	18.49	0.03	0.03	0.60	15.65	0.18	1.16	100.12	0%	5%	94%
Musher Lake Pluton													
7075-k(9)	64.17	0.02	18.19	0.08	0.03	0.58	15.90	0.00	1.34	100.32	1%	5%	94%
Botham Stock													
7066-k(12)	64.11	0.02	18.23	0.05	0.03	0.39	16.43	0.00	0.76	100.03	1%	3%	96%
Meigund Stock													
7131-k(5)	64.54	0.02	18.46	0.00	0.05	0.33	16.23	0.11	0.87	100.61	0%	3%	97%
Terrace Bay Batholith													
7171-k(10)	64.31	0.01	18.60	0.02	0.08	1.00	15.09	0.14	1.35	100.59	0%	9%	91%
White River Pluton													
7041-k(8)	64.16	0.04	18.47	0.11	0.06	0.46	16.22	0.00	1.14	100.66	1%	4%	95%
7042-k(9)	64.06	0.02	18.32	0.07	0.06	0.47	16.19	0.00	1.04	100.24	1%	4%	95%
7043-k(9)	64.60	0.01	18.44	0.06	0.07	1.22	15.32	0.00	0.79	100.52	1%	11%	89%
Dotted Lake Batholith													
7050-k(8)	64.33	0.03	18.29	0.06	0.05	0.46	16.43	0.00	0.61	100.27	1%	4%	95%
7079-k(9)	65.17	0.03	17.95	0.05	0.05	0.43	16.67	0.00	0.27	100.62	1%	4%	96%
Picture Island Stock													
7224-k(8)	64.76	0.01	18.44	0.02	0.01	0.58	15.85	0.10	0.74	100.52	0%	5%	95%

Potassium Feldspar Analyses

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	CaO	FeO	Na ₂ O	K ₂ O	SrO	BaO	Total	An	Ab	Or
Ogilvie Island Granodiorite													
7324-k(11)	64.57	0.00	18.32	0.01	0.04	0.51	15.95	0.08	0.54	100.02	0%	5%	95%
Pukaskwa Batholith													
7276-k(4)	64.33	0.01	18.58	0.02	0.02	0.58	15.67	0.14	1.17	100.51	0%	5%	95%
7255-k(5)	64.17	0.01	18.43	0.03	0.04	0.60	15.64	0.16	1.10	100.17	0%	5%	94%
Black-Pic Batholith													
7146-k(7)	64.43	0.03	18.49	0.01	0.03	0.47	15.94	0.16	0.87	100.43	0%	4%	96%
7213-k(8)	64.28	0.00	18.44	0.03	0.02	0.46	15.94	0.09	0.96	100.22	0%	4%	96%

Analytical Conditions: 20kV, 15nA, spot size 10 microns.
 Routine: Custom EDS/WDS feldspar routine.
 Correction Procedure: ZAF-4

Amphibole Analyses

Appendix E

Amphibole Analyses

This table lists average electron microprobe analyses of amphibole for samples investigated in detail.

The number in brackets following the sample number indicates the number of individual analyses used to compute the average composition.

Sample SiO₂ Al₂O₃ MgO Na₂O F Cr₂O₃ MnO FeO Cl K₂O CaO TiO₂ F=O Cl=O Total V₂O₅ BaO NiO ZnO
Cedar Lake Pluton (various phases and adjacent external dike)

7004A(11)	43.12	9.85	9.36	1.44	0.22	0.04	0.35	19.92	0.01	1.20	11.46	0.79	-0.09	0.00	97.45			
7004B(6)	44.44	9.05	10.67	1.35	0.17	0.04	0.38	18.21	0.01	1.07	11.79	0.70	-0.07	0.00	97.80			
7018A(5) (ulmf clot)	44.92	8.69	11.15	1.67	0.34	0.08	0.37	17.64	0.00	1.09	11.28	0.64	-0.14	0.00	97.72			
7018A(6)	45.78	8.05	11.54	1.37	0.26	0.03	0.39	17.40	0.00	0.92	11.50	0.64	-0.11	0.00	97.77			
7018B(10)	49.06	6.11	14.49	1.12	0.40	0.06	0.33	13.13	0.01	0.66	11.93	0.40	-0.17	0.00	97.52			
7031(9)	42.28	10.22	8.75	1.37	0.20	0.02	0.33	21.10	0.01	1.29	11.47	0.54	-0.08	0.00	97.49			
7032(10)	41.35	11.07	8.03	1.56	0.35	0.01	0.39	22.08	0.01	1.50	11.42	0.53	-0.15	0.00	98.14			
7033A(8)	43.74	9.79	9.58	1.44	0.26	0.01	0.35	19.74	0.00	1.14	11.42	0.72	-0.11	0.00	98.07			
7067(8) (dior enclave)	48.99	6.61	13.52	0.99	0.30	0.26	0.35	14.33	0.01	0.63	12.02	0.23	-0.13	0.00	98.10			
7067(12) (enclave rim)	46.54	8.10	11.84	1.36	0.30	0.19	0.37	16.49	0.01	0.90	11.68	0.50	-0.13	0.00	98.13			
7067(8)	44.47	9.20	10.16	1.34	0.21	0.01	0.35	18.70	0.01	1.05	11.57	0.86	-0.09	0.00	97.85			

Heron Bay Pluton

7071(7)	42.92	10.00	8.75	1.40	0.30	0.02	0.38	20.92	0.00	1.18	11.46	0.61	-0.13	0.00	97.82			
7096(19)	44.07	9.19	9.72	1.40	0.24	0.03	0.37	19.54	0.00	0.91	11.50	0.69	-0.10	0.00	97.77	0.05	0.05	0.03 0.08
7099(12)	41.69	10.71	8.42	1.43	0.31	0.03	0.30	21.13	0.01	1.33	11.46	0.62	-0.13	0.00	97.29			
7152(9)	42.89	10.78	9.29	1.60	0.19	0.04	0.34	19.48	0.01	1.36	11.24	0.92	-0.08	0.00	98.12	0.05		0.02

Gowan Lake Pluton

7175(12)	46.22	7.94	11.52	1.42	0.14	0.03	0.42	16.65	0.02	0.89	11.44	1.29	-0.06	0.00	98.03	0.06	0.07	0.00 0.02
7183(11)	44.84	9.04	10.85	1.54	1.54	0.00	0.46	17.21	0.03	1.10	11.43	1.43	-0.65	-0.01	100.11	0.08	1.14	0.00 0.09
7233(10)	45.98	7.91	11.64	1.36	0.16	0.02	0.44	16.73	0.02	0.90	11.42	1.14	-0.07	0.00	97.79	0.05	0.04	0.03 0.06
7250(10)	45.09	8.26	10.64	1.59	0.23	0.02	0.49	17.98	0.03	1.07	11.20	1.41	-0.10	-0.01	98.07	0.05	0.06	0.02 0.04

Amphibole Analyses

Sample	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	F	Cr ₂ O ₃	MnO	FeO	Cl	K ₂ O	CaO	TiO ₂	F=O	Cl=O	Total	V ₂ O ₅	BaO	NiO	ZnO
Amphibole after Pyroxene- Gowan Lake Pluton																			
7183(1)	51.74	2.70	12.60	0.84	0.10	0.02	0.53	11.60	0.04	0.22	18.33	0.44	-0.04	-0.02	99.34	0.00	0.08	0.00	0.10
7250(2)	53.82	1.77	15.49	0.30	0.19	0.00	0.44	12.87	0.01	0.13	12.52	0.03	-0.08	0.00	97.60	0.04	0.00	0.01	0.00
Fourbay Lake Pluton																			
7239(7)	44.69	8.33	10.58	1.60	0.22	0.01	0.54	18.05	0.06	1.06	11.20	1.37	-0.09	-0.01	97.71	0.04	0.02	0.01	0.04
7240(14)	44.62	8.90	10.62	1.52	0.16	0.01	0.46	17.69	0.02	1.07	11.45	1.43	-0.07	-0.01	98.09	0.07	0.05	0.01	0.07
Amphibole after Pyroxene- Fourbay Lake Pluton																			
7239(2)	53.23	2.16	15.47	0.46	0.19	0.02	0.53	12.93	0.01	0.17	12.21	0.05	-0.08	0.00	97.42	0.05	0.01	0.01	0.09
Cedar Creek Stock																			
7297(13)	42.79	10.21	9.13	1.38	0.34	0.02	0.43	20.49	0.00	1.36	11.44	0.52	-0.15	0.00	98.03	0.04			0.02
Musher Lake Pluton																			
7075(12)	43.48	9.85	9.75	1.38	0.16	0.03	0.39	19.34	0.00	1.15	11.58	0.97	-0.07	0.00	98.20	0.07	0.05	0.04	0.03
Melgund Stock																			
7131(13)	51.19	4.60	14.02	0.60	0.10	0.06	0.31	14.41	0.00	0.34	12.25	0.19	-0.04	0.00	98.10	0.05			0.02
Terrace Bay Batholith																			
7171(11)	49.08	5.95	14.47	1.23	0.32	0.03	0.51	13.31	0.02	0.63	11.77	0.75	-0.13	0.00	97.98	0.04			0.02
White River Pluton																			
7041(10)	46.65	8.59	11.64	1.03	0.09	0.05	0.32	16.52	0.01	0.75	11.90	0.55	-0.04	0.00	98.07				
7042(8)	45.42	8.71	10.37	1.12	0.11	0.03	0.40	18.33	0.01	0.87	11.70	0.61	-0.05	0.00	97.63				
7043(8)	45.99	7.93	10.73	1.26	0.12	0.04	0.40	18.58	0.01	0.81	11.60	0.66	-0.05	0.00	98.06				

Amphibole Analyses

Sample	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	F	Cr ₂ O ₃	MnO	FeO	Cl	K ₂ O	CaO	TiO ₂	F=O	Cl=O	Total	V ₂ O ₅	BaO	NiO	ZnO
Ogilvie Island Granodiorite																			
7324(5)	49.82	6.60	14.82	1.03	0.19	0.09	0.29	12.18	0.00	0.51	11.88	0.54	-0.08	0.00	98.00	0.07		0.05	
Pukaskwa Batholith																			
7255(9)	43.35	10.06	9.43	1.45	0.27	0.02	0.52	19.67	0.01	1.24	11.50	0.56	-0.11	0.00	98.03	0.06		0.02	
Black-Pic Batholith																			
7213(8)	41.45	11.63	7.54	1.17	0.13	0.01	0.54	21.68	0.01	1.44	11.45	0.79	-0.06	0.00	97.82	0.04		0.01	

Analytical Conditions: 20KV, 215nA, spot size 7 microns
 Routine: Amphibole Routine - Combined EDS/WDS acquisition.
 Correction Procedure: ZAF-4

Appendix F

Biotite Analyses

This table lists average electron microprobe analyses of biotite for samples investigated in detail.

The number in brackets following the sample number indicates the number of individual analyses used to compute the average composition.

Sample	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	F	Cr ₂ O ₃	MnO	FeO	Cl	K ₂ O	CaO	TiO ₂	F=O	Cl=O	Total	V ₂ O ₅	BaO	NiO	ZnO
Cedar Lake Pluton																			
7004A-b(5)	36.70	15.30	11.26	0.07	0.58	0.02	0.24	19.85	0.01	9.81	0.00	1.85	-0.24	0.00	95.44				
7004B-b(3)	37.35	15.35	12.55	0.08	0.52	0.02	0.23	18.49	0.01	9.70	0.02	1.93	-0.22	0.00	96.02				
7018A-b CL(4)	37.63	15.13	13.57	0.09	0.83	0.04	0.25	16.71	0.01	9.80	0.04	1.56	-0.35	0.00	95.30				
7018A-b(5)	37.57	14.84	13.18	0.08	0.70	0.03	0.26	17.88	0.00	9.73	0.07	1.72	-0.30	0.00	95.77				
7018B-b(5)	38.09	14.53	15.23	0.11	0.98	0.09	0.21	14.95	0.00	9.87	0.02	1.77	-0.41	0.00	95.43				
7031-b(4)	37.01	15.05	11.51	0.07	0.69	0.02	0.24	19.74	0.01	9.81	0.04	1.46	-0.29	0.00	95.35				
7032-b(8)	37.33	15.50	11.57	0.09	0.81	0.01	0.28	19.45	0.01	9.84	0.03	1.51	-0.34	0.00	96.07				
7033A-b(4)	37.46	15.46	11.69	0.12	0.71	0.02	0.22	19.34	0.00	9.59	0.06	1.64	-0.30	0.00	96.02				
Heron Bay Pluton																			
7071-b(1)	36.51	15.29	11.25	0.06	0.90	0.03	0.26	20.50	0.00	9.79	0.03	1.70	-0.38	0.00	95.95				
7096-b(7)	37.10	15.37	11.83	0.07	0.62	0.01	0.23	19.42	0.00	9.63	0.08	1.57	-0.26	0.00	96.44	0.02	0.10	0.03	0.19
7099-b(4)	37.07	15.67	11.20	0.06	0.67	0.02	0.21	20.01	0.00	9.51	0.01	1.57	-0.28	0.00	95.73				
7152-b(8)	36.86	15.54	12.23	0.07	0.34	0.04	0.25	19.10	0.01	9.87	0.02	1.65	-0.14	0.00	96.03	0.04		0.01	
Gowan Lake Pluton																			
7183-b(8)	36.84	14.71	11.55	0.07	0.30	0.00	0.28	19.28	0.04	9.91	0.02	3.74	-0.13	-0.01	97.03	0.07	0.15	0.02	0.06
7233-b(8)	36.99	15.20	12.17	0.05	0.34	0.03	0.31	18.78	0.01	10.03	0.04	1.98	-0.14	0.00	95.94	0.09	0.12	0.02	0.04
7250-b(2)	37.46	15.03	11.99	0.07	0.54	0.04	0.30	19.81	0.02	9.98	0.06	1.60	-0.23	-0.02	97.24	0.08	0.20	0.04	0.08
Fourbay Lake Pluton																			
7239-b(8)	37.26	14.49	12.17	0.07	0.46	0.01	0.33	19.58	0.07	9.68	0.03	1.85	-0.19	-0.02	96.03	0.05	0.06	0.03	0.11
7240-b(4)	36.79	14.65	11.35	0.07	0.31	0.01	0.26	19.51	0.04	9.79	0.06	3.07	-0.13	-0.01	96.22	0.06	0.21	0.01	0.05
Cedar Creek Stock																			
7297-b(7)	37.82	15.39	12.76	0.05	0.84	0.01	0.32	17.52	0.01	10.35	0.03	1.38	-0.35	0.00	96.49	0.02		0.01	

Biotite Analyses

Sample	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	F	Cr ₂ O ₃	MnO	FeO	Cl	K ₂ O	CaO	TiO ₂	F=O	Cl=O	Total	V ₂ O ₅	BaO	NiO	ZnO
Musher Lake Pluton																			
7075-b(8)	36.98	15.52	11.81	0.07	0.35	0.01	0.28	19.86	0.00	9.72	0.03	1.87	-0.15	0.00	96.86	0.05	0.16	0.01	0.08
Botham Stock																			
7066-b(10)	38.07	15.27	13.61	0.06	0.98	0.01	0.22	16.78	0.01	9.78	0.05	1.23	-0.41	0.00	95.64				
Terrace Bay Batholith																			
7171-b(8)	38.33	14.72	14.62	0.05	0.80	0.04	0.39	15.24	0.02	10.39	0.03	2.12	-0.34	0.00	96.82	0.04		0.03	
Dotted Lake Batholith																			
7050-b(6)	38.53	15.64	12.47	0.06	1.23	0.01	0.59	16.86	0.00	9.84	0.02	1.24	-0.52	0.00	95.96				
7079-b(12)	36.74	16.29	10.28	0.07	0.62	0.01	0.55	19.27	0.01	9.77	0.01	1.97	-0.26	0.00	95.31				
Picture Island Stock																			
7224-b(10)	36.33	16.74	9.93	0.08	0.30	0.00	0.35	20.67	0.01	10.29	0.02	2.04	-0.13	0.00	96.82	0.04		0.01	
Ogilvie Island Granodiorite																			
7324-b(8)	37.26	16.22	13.62	0.08	0.55	0.05	0.23	16.44	0.01	10.16	0.05	1.37	-0.23	0.00	96.11	0.05		0.05	
Pukaskwa Batholith																			
7276-b(8)	36.19	16.72	9.23	0.08	0.30	0.01	0.38	21.55	0.01	10.00	0.03	2.28	-0.13	0.00	96.83	0.03		0.02	
7255-b(5)	37.37	15.91	11.90	0.09	0.57	0.04	0.33	18.34	0.01	10.09	0.03	1.77	-0.24	0.00	96.53	0.04		0.03	
Black-Pic Batholith																			
7146-b(9)	36.55	16.60	9.45	0.05	0.40	0.01	0.23	20.85	0.01	10.33	0.03	2.34	-0.17	0.00	96.89	0.02		0.01	
7213-b(16)	36.20	16.54	9.45	0.05	0.22	0.01	0.37	20.90	0.01	10.32	0.04	2.69	-0.09	0.00	96.83	0.02		0.01	

Appendix G

Pyroxene Analyses

This table lists individual and average electron microprobe analyses of pyroxenes from the Gowan Lake and Fourbay Lake plutons

Average analyses for samples are bolded with the number in brackets following the sample number being the number of analyses incorporated in the average

Analysis	SiO ₂	TiO ₂	Al ₂ O ₃	V ₂ O ₅	Cr ₂ O ₃	MgO	CaO	MnO	FeO	NiO	ZnO	BaO	Na ₂ O	K ₂ O	F	Cl	Total
Gowan Lake Pluton																	
7183px 1	52.96	0.12	1.06	0.05	0.01	12.24	22.49	0.66	9.82	0.00	0.00	0.10	0.84	0.02	0.00	0.00	100.39
7183px 3	52.89	0.12	1.01	0.06	0.02	12.21	22.68	0.65	9.35	0.00	0.21	0.00	0.86	0.01	0.01	0.02	100.10
7183px 4	52.88	0.13	1.09	0.02	0.05	12.10	22.68	0.69	9.65	0.03	0.00	0.10	0.84	0.00	0.00	0.01	100.27
7183px 5	52.97	0.14	1.19	0.00	0.00	12.04	22.38	0.66	10.14	0.00	0.05	0.08	0.87	0.04	0.06	0.00	100.63
7183avg(4)	52.93	0.13	1.09	0.03	0.02	12.15	22.56	0.67	9.74	0.01	0.07	0.07	0.85	0.02	0.02	0.01	100.35
7250px 2	52.87	0.11	0.95	0.00	0.06	11.34	22.27	0.59	11.10	0.04	0.03	0.00	1.06	0.00	0.11	0.01	100.52
Fourbay Lake Pluton																	
7239px 1	52.17	0.16	1.25	0.07	0.05	11.85	21.24	0.65	10.59	0.00	0.00	0.00	1.03	0.07	0.07	0.02	99.06
7239px 2	51.51	0.34	2.32	0.00	0.06	12.10	19.67	0.61	11.28	0.01	0.07	0.00	1.09	0.18	0.02	0.01	99.17
7239avg(2)	51.84	0.25	1.79	0.04	0.06	11.98	20.46	0.63	10.94	0.01	0.04	0.00	1.06	0.13	0.05	0.02	99.12
7240px 1	52.30	0.16	1.42	0.08	0.05	12.44	21.38	0.59	10.48	0.00	0.08	0.00	0.73	0.08	0.00	0.01	99.79
7240px 2	52.54	0.16	1.15	0.03	0.04	12.13	22.37	0.64	10.27	0.02	0.05	0.00	0.83	0.01	0.01	0.02	100.26
7240px 3	52.99	0.11	1.12	0.00	0.00	11.89	22.67	0.65	10.77	0.00	0.16	0.05	0.85	0.02	0.08	0.02	101.36
7240px 4 c	53.05	0.08	1.02	0.07	0.00	12.02	22.27	0.59	10.52	0.01	0.03	0.03	0.80	0.03	0.08	0.00	100.60
7240px 4 r	52.86	0.14	1.03	0.02	0.00	12.12	22.54	0.61	10.11	0.00	0.05	0.05	0.82	0.01	0.08	0.00	100.44
7240avg(5)	52.75	0.13	1.15	0.04	0.02	12.12	22.25	0.62	10.43	0.01	0.07	0.03	0.81	0.03	0.05	0.01	100.49

Chlorite Analyses

Appendix H Chlorite Analyses

This table lists individual electron microprobe analyses of chlorite.

All chlorites analyzed are interpreted to be secondary after biotite.

Sample	Associated with	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	F	Cr ₂ O ₃	MnO	FeO	Cl	K ₂ O	CaO	TiO ₂	F=O	Cl=O	Total	V ₂ O ₅	NiO
Heron Bay Pluton																		
7071-1chl		27.47	18.01	14.37	0.01	0.14	0.02	0.30	27.92	0.01	0.03	0.08	0.06	-0.06	0.00	88.35		
White River Pluton																		
7041-1chl		28.32	17.39	17.54	0.00	0.07	0.16	0.30	23.13	0.00	0.01	0.16	0.08	-0.03	0.00	87.13		
7041-2chl		27.52	18.77	16.82	0.00	0.07	0.03	0.39	23.97	0.01	0.01	0.04	0.03	-0.03	0.00	87.63		
Ogilvie Island Granodiorite																		
7324-1chl	biotite 7324-1b	27.65	18.15	17.80	0.00	0.05	0.01	0.36	23.46	0.01	0.01	0.03	0.04	-0.02	0.00	87.64	0.02	0.04
7324-3chl	biotite 7324-3b	28.88	16.50	19.07	0.00	0.15	0.01	0.32	21.38	0.00	0.03	0.04	0.08	-0.06	0.00	86.52	0.00	0.05
7324-8chl	biotite 7324-8b	28.95	17.01	19.38	0.01	0.11	0.00	0.33	20.97	0.03	0.04	0.10	0.02	-0.05	-0.01	87.00	0.00	0.05

Appendix I

Epidote Analyses

This table lists individual and average electron microprobe analyses of magmatic epidote from selected plutons.

Average analyses for samples are bolded with the number in brackets following the sample number being the number of analyses incorporated in the average

Sample	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	F	Cr ₂ O ₃	MnO	FeO	Cl	K ₂ O	CaO	TiO ₂	F=O	Cl=O	Total
Cedar Lake Pluton															
7004A-1ep	36.50	22.32	0.01	0.01	0.05	0.04	0.13	14.36	0.00	0.02	22.04	0.05	-0.02	0.00	95.50
7004A-2ep	36.21	21.83	0.01	0.02	0.03	0.05	0.16	14.86	0.00	0.02	21.15	0.11	-0.01	0.00	94.44
7004A-ep(2)	36.36	22.07	0.01	0.01	0.04	0.04	0.15	14.61	0.00	0.02	21.59	0.08	-0.02	0.00	94.97
7004B-1ep	36.40	21.92	0.05	0.00	0.00	0.06	0.11	13.70	0.00	0.01	22.14	0.12	0.00	0.00	94.49
7004B-ep(1)	36.40	21.92	0.05	0.00	0.00	0.06	0.11	13.70	0.00	0.01	22.14	0.12	0.00	0.00	94.49
Heron Bay Pluton															
7152-1ep	37.77	24.00	0.09	0.00	0.09	0.02	0.13	13.22	0.00	0.01	23.11	0.13	-0.04	0.00	98.69
7152-2ep	37.80	23.89	0.03	0.01	0.07	0.03	0.14	13.34	0.00	0.00	23.14	0.07	-0.03	0.00	98.59
7152-ep(2)	37.79	23.95	0.06	0.01	0.08	0.03	0.14	13.28	0.00	0.01	23.13	0.10	-0.04	0.00	98.64
Gowan Lake Pluton															
7175-1ep	37.00	19.84	0.00	0.01	0.05	0.03	0.13	16.97	0.00	0.05	22.62	0.15	-0.02	0.00	97.25
7175-ep(1)	37.00	19.84	0.00	0.01	0.05	0.03	0.13	16.97	0.00	0.05	22.62	0.15	-0.02	0.00	97.25
7233-1ep	37.49	22.76	0.02	0.01	0.04	0.09	0.13	14.07	0.01	0.00	23.01	0.07	-0.02	0.00	97.62
7233-ep(1)	37.49	22.76	0.02	0.01	0.04	0.09	0.13	14.07	0.01	0.00	23.01	0.07	-0.02	0.00	97.62
Melgund Stock															
7131-1ep	37.92	25.08	0.10	0.00	0.00	0.01	0.21	11.81	0.01	0.00	22.71	0.17	0.00	0.00	98.14
7131-ep(1)	37.92	25.08	0.10	0.00	0.00	0.01	0.21	11.81	0.01	0.00	22.71	0.17	0.00	0.00	98.14
Ogilvie Island Granodiorite															
7324-1ep	37.80	24.12	0.05	0.00	0.06	0.00	0.18	12.75	0.00	0.00	23.02	0.12	-0.03	0.00	98.17
7324-2ep	37.94	24.05	0.07	0.02	0.07	0.09	0.12	12.91	0.01	0.00	23.03	0.07	-0.03	0.00	98.50
7324-3ep	37.78	24.19	0.08	0.02	0.00	0.12	0.14	12.70	0.01	0.00	22.80	0.10	0.00	0.00	98.06
7324-ep(3)	37.84	24.12	0.07	0.01	0.04	0.07	0.15	12.79	0.01	0.00	22.95	0.10	-0.02	0.00	98.24
Pukaskwa Batholith															
7276-1ep	37.70	24.94	0.03	0.01	0.03	0.02	0.30	12.26	0.00	0.02	22.99	0.16	-0.01	0.00	98.49
7276-2ep	38.20	25.32	0.05	0.00	0.00	0.00	0.26	11.87	0.00	0.00	23.12	0.08	0.00	0.00	98.99
7276-3ep	37.83	25.71	0.16	0.00	0.03	0.04	0.28	11.63	0.00	0.00	23.10	0.15	-0.01	0.00	99.00
7276-ep(3)	37.91	25.32	0.08	0.00	0.02	0.02	0.28	11.92	0.00	0.01	23.07	0.13	-0.01	0.00	98.83

Oxide Analyses

Tabulation of oxide mineral chemistry for intermediate to felsic intrusive rocks from the Hemlo greenstone belt area

Abbreviations	Mt= Magnetite	TiMt= Titanium-bearing magnetite	Il= Ilmenite												
	* = sample not used to compute average														
	# = analysis with beam impinging on adjacent minerals														
Average analyses for samples are bolded with the number of analyses incorporated in the average in brackets															
Sample	SiO ₂	TiO ₂	Nb ₂ O ₅	Al ₂ O ₃	Cr ₂ O ₃	V ₂ O ₅	MgO	CaO	MnO	FeO	NiO	ZnO	Total Fe ₂ O ₃	FeO	Total
Gowan Lake Pluton															
7175-01	0.03	0.11	0.00	0.06	0.17	0.46	0.00	0.07	0.02	92.43	0.00	0.02	93.37	67.34	31.84
7175-02	0.04	0.02	0.00	0.06	0.39	0.40	0.00	0.01	0.02	92.08	0.07	0.00	93.08	67.23	31.59
7175-03	0.00	0.01	0.00	0.06	0.20	0.25	0.00	0.04	0.00	91.88	0.06	0.03	92.52	67.55	31.09
7175-Mt(3)	0.02	0.05	0.00	0.06	0.25	0.37	0.00	0.04	0.01	92.13	0.04	0.02	92.99	67.37	31.51
7183-01	0.03	0.00	0.00	0.15	0.09	0.41	0.00	0.00	0.05	91.75	0.00	0.00	92.48	67.00	31.46
7183-02	0.02	0.00	0.00	0.10	0.11	0.41	0.00	0.02	0.11	92.11	0.10	0.00	92.98	67.45	31.42
7183-03 * #	3.16	49.87	0.06	1.83	0.00	0.08	0.55	0.19	2.64	36.85	0.02	0.00	95.24	0.00	36.85
7183-04	0.05	0.00	0.02	0.00	0.05	0.06	0.00	0.03	0.07	92.61	0.00	0.00	92.90	68.43	31.04
7183-05 *	0.10	27.56	0.07	0.05	0.00	0.06	0.03	0.05	0.99	65.74	0.03	0.00	94.68	12.41	54.58
7183-06 *	0.03	32.20	0.01	0.01	0.05	0.12	0.05	0.03	0.08	61.07	0.05	0.00	93.69	2.21	59.08
7183-07	0.01	0.00	0.03	0.16	0.09	0.41	0.03	0.00	0.02	92.37	0.03	0.01	93.16	67.50	31.63
7183-09	0.02	0.06	0.01	0.12	0.10	0.54	0.00	0.01	0.05	92.04	0.09	0.00	93.03	66.97	31.77
7183-Mt(5)	0.03	0.01	0.01	0.11	0.09	0.37	0.01	0.01	0.06	92.18	0.04	0.00	92.91	67.47	31.46
7183-08	0.07	61.93	0.03	0.07	0.04	0.00	0.05	0.12	1.36	32.66	0.00	0.00	96.33	0.00	32.66
7183-II(1)	0.07	61.93	0.03	0.07	0.04	0.00	0.05	0.12	1.36	32.66	0.00	0.00	96.33	0.00	32.66
7233-01	0.01	0.03	0.10	0.08	0.20	0.20	0.01	0.01	0.02	93.27	0.05	0.00	93.96	68.46	31.67
7233-02	0.00	0.01	0.06	0.06	0.26	0.37	0.00	0.03	0.05	92.58	0.09	0.00	93.50	67.76	31.61
7233-03	0.02	0.00	0.01	0.08	0.29	0.16	0.00	0.01	0.00	92.56	0.09	0.12	93.35	68.22	31.18
7233-04	0.03	0.00	0.03	0.05	0.32	0.12	0.02	0.00	0.00	92.57	0.03	0.00	93.17	68.14	31.25
7233-05	0.01	0.04	0.00	0.00	0.27	0.26	0.03	0.12	0.04	92.34	0.05	0.09	93.24	67.99	31.16
7233-08	0.02	0.04	0.00	0.05	0.17	0.38	0.02	0.10	0.02	92.58	0.00	0.05	93.42	67.81	31.56
7233-Mt(6)	0.02	0.02	0.03	0.05	0.25	0.25	0.01	0.05	0.02	92.65	0.05	0.04	93.44	68.06	31.41

Oxide Analyses

Sample	SiO ₂	TiO ₂	Nb ₂ O ₅	Al ₂ O ₃	Cr ₂ O ₃	V ₂ O ₅	MgO	CaO	MnO	FeO	NiO	ZnO	Total	Fe ₂ O ₃	FeO	Total
7233-o6	0.01	8.89	0.00	0.01	0.32	0.54	0.00	0.11	0.13	81.57	0.11	0.05	91.74	47.66	38.69	96.51
7233-TiMt(1)	0.01	8.89	0.00	0.01	0.32	0.54	0.00	0.11	0.13	81.57	0.11	0.05	91.74	47.66	38.69	96.51
7233-o7	0.01	49.16	0.00	0.04	0.08	0.19	0.21	0.10	2.67	46.15	0.02	0.00	98.63	5.41	41.29	99.17
7233-II(1)	0.01	49.16	0.00	0.04	0.08	0.19	0.21	0.10	2.67	46.15	0.02	0.00	98.63	5.41	41.29	99.17
7250-o1	0.02	0.06	0.02	0.00	0.15	0.21	0.00	0.02	0.03	93.64	0.00	0.00	94.14	68.80	31.74	101.04
7250-o2	0.02	0.00	0.00	0.01	0.18	0.19	0.00	0.01	0.01	92.73	0.07	0.00	93.22	68.28	31.29	100.06
7250-o3	0.03	0.03	0.00	0.10	0.08	0.43	0.00	0.02	0.04	93.95	0.05	0.04	94.77	68.67	32.17	101.65
7250-o4	0.01	0.00	0.00	0.06	0.16	0.58	0.01	0.03	0.07	92.81	0.06	0.04	93.83	67.64	31.95	100.61
7250-o5	0.01	0.00	0.02	0.00	0.22	0.42	0.00	0.01	0.03	92.57	0.03	0.00	93.31	67.68	31.68	100.10
7250-o6 *	0.06	0.38	0.00	0.15	0.00	0.15	0.03	0.00	0.01	89.24	0.00	0.07	90.11	65.21	30.56	96.64
7250-o7	0.00	0.00	0.00	0.08	0.07	0.25	0.01	0.04	0.05	93.40	0.06	0.00	93.96	68.74	31.55	100.85
7250-o8	0.01	0.00	0.01	0.10	0.13	0.39	0.00	0.01	0.02	92.57	0.02	0.04	93.30	67.72	31.63	100.09
7250-Mt(7)	0.01	0.01	0.01	0.05	0.14	0.35	0.00	0.02	0.04	93.10	0.04	0.02	93.79	68.22	31.72	100.63
7250-o9	0.02	8.19	0.00	0.03	0.05	0.53	0.08	0.03	0.24	83.22	0.05	0.00	92.44	49.94	38.28	97.45
7250-TiMt(1)	0.02	8.19	0.00	0.03	0.05	0.53	0.08	0.03	0.24	83.22	0.05	0.00	92.44	49.94	38.28	97.45
7250-o10	0.00	50.00	0.00	0.03	0.12	0.00	0.19	0.03	2.96	45.84	0.02	0.00	99.19	4.76	41.56	99.66
7250-II(1)	0.00	50.00	0.00	0.03	0.12	0.00	0.19	0.03	2.96	45.84	0.02	0.00	99.19	4.76	41.56	99.66
Fourbay Lake Pluton																
7239-o1	0.01	0.05	0.03	0.11	0.08	0.33	0.00	0.02	0.20	91.93	0.01	0.03	92.79	67.43	31.26	99.55
7239-o2	0.02	0.00	0.00	0.06	0.03	0.35	0.02	0.01	0.12	92.67	0.01	0.05	93.34	68.04	31.44	100.16
7239-o3	0.01	0.00	0.00	0.16	0.00	0.39	0.04	0.00	0.07	92.64	0.03	0.06	93.41	67.90	31.55	100.21
7239-o4	0.03	0.00	0.00	0.06	0.00	0.45	0.02	0.00	0.00	92.45	0.03	0.05	93.10	67.58	31.65	99.87
7239-o6	0.02	0.05	0.00	0.04	0.12	0.24	0.10	0.02	0.07	92.57	0.02	0.00	93.25	68.14	31.26	100.08
7239-o7	0.04	0.00	0.03	0.07	0.00	0.27	0.05	0.00	0.00	92.32	0.00	0.01	92.78	67.78	31.33	99.57
7239-Mt(6)	0.02	0.02	0.01	0.08	0.04	0.34	0.04	0.01	0.08	92.43	0.02	0.03	93.11	67.81	31.42	99.91
7239-o5	0.02	13.01	0.00	0.07	0.04	0.33	0.03	0.02	0.33	78.70	0.05	0.00	92.61	40.54	42.22	96.67
7239-o8	0.02	9.10	0.00	0.10	0.00	0.54	0.00	0.04	0.11	82.04	0.00	0.06	92.02	47.61	39.20	96.79

Oxide Analyses

Sample	SiO ₂	TiO ₂	Nb ₂ O ₅	Al ₂ O ₃	Cr ₂ O ₃	V ₂ O ₅	MgO	CaO	MnO	FeO	NiO	ZnO	Total	Fe ₂ O ₃	FeO	Total
7239-o9	0.16	9.44	0.00	0.18	0.06	0.37	0.02	0.06	0.29	82.25	0.00	0.00	92.83	47.52	39.50	97.59
7239-TiMt(3)	0.07	10.52	0.00	0.12	0.03	0.41	0.02	0.04	0.24	81.00	0.02	0.02	92.49	45.22	40.31	97.02
7240-o1	0.01	0.00	0.01	0.18	0.00	0.37	0.00	0.00	0.08	92.39	0.05	0.08	93.16	67.71	31.46	99.95
7240-o2	0.00	0.00	0.00	0.02	0.06	0.50	0.00	0.01	0.11	93.06	0.01	0.04	93.81	68.01	31.86	100.62
7240-o4	0.01	0.00	0.01	0.09	0.13	0.46	0.00	0.00	0.07	92.93	0.06	0.07	93.84	67.93	31.81	100.65
7240-o5	0.00	0.00	0.00	0.00	0.09	0.39	0.00	0.06	0.07	93.74	0.01	0.00	94.37	68.74	31.89	101.26
7240-o6	0.01	0.01	0.00	0.02	0.08	0.47	0.02	0.01	0.01	94.47	0.04	0.09	95.24	69.10	32.30	102.17
7240-o7	0.03	0.00	0.00	0.06	0.11	0.58	0.00	0.01	0.04	93.16	0.06	0.00	94.04	67.80	32.15	100.84
7240-o9	0.01	0.35	0.00	0.00	0.05	0.49	0.00	0.01	0.06	93.49	0.02	0.00	94.48	67.83	32.46	101.28
7240-Mt(7)	0.01	0.05	0.00	0.05	0.07	0.47	0.00	0.01	0.06	93.32	0.04	0.04	94.13	68.16	31.99	100.97
7240-o3 * #	0.05	65.44	0.05	0.39	0.00	0.53	0.15	3.39	2.50	23.81	0.00	0.36	96.66	0.00	23.81	96.66
7240-o8	0.01	51.29	0.00	0.02	0.11	0.00	0.03	0.08	9.55	38.72	0.00	0.71	100.53	0.00	38.72	100.53
7240-II(1)	0.01	51.29	0.00	0.02	0.11	0.00	0.03	0.08	9.55	38.72	0.00	0.71	100.53	0.00	38.72	100.53
Cedar Creek Stock																
7297-1ox	0.02	0.01	0.04	0.00	0.03	0.27	0.01	0.00	0.00	93.58	0.00	0.03	93.99	68.72	31.75	100.88
7297-2ox	0.03	0.00	0.00	0.00	0.03	0.29	0.05	0.00	0.00	93.77	0.02	0.01	94.21	68.89	31.79	101.11
7297-3ox	0.02	0.04	0.04	0.00	0.03	0.27	0.00	0.00	0.00	92.70	0.04	0.04	93.18	68.03	31.49	99.99
7297-4ox	0.05	0.01	0.04	0.00	0.03	0.35	0.05	0.00	0.02	92.56	0.03	0.02	93.15	67.81	31.55	99.95
7297-5ox	0.00	0.00	0.02	0.00	0.07	0.17	0.01	0.00	0.00	92.84	0.00	0.02	93.14	68.41	31.28	99.99
7297-6ox	0.03	0.00	0.07	0.00	0.04	0.26	0.00	0.00	0.00	92.54	0.01	0.04	92.98	67.92	31.43	99.79
7297-7ox	0.04	0.04	0.00	0.00	0.03	0.23	0.00	0.00	0.04	92.68	0.03	0.04	93.12	68.15	31.36	99.95
7297-Mt(7)	0.03	0.01	0.03	0.00	0.04	0.26	0.02	0.01	0.01	92.95	0.02	0.03	93.40	68.28	31.52	100.24
Melgund Stock																
7131-1ox * #	3.82	0.01	0.02	0.00	0.00	0.00	0.17	0.00	0.00	77.18	0.26	0.00	81.46	50.78	31.48	86.55
7131-2ox	0.06	0.42	0.01	0.00	0.19	0.57	0.03	0.00	0.00	91.77	0.03	0.01	93.09	66.15	32.24	99.72
7131-3ox	0.01	0.27	0.05	0.00	0.22	0.56	0.03	0.00	0.00	89.31	0.00	0.00	90.46	64.54	31.23	96.92
7131-4ox * #	2.72	0.00	0.05	0.00	0.00	0.03	0.33	0.00	0.00	75.74	0.14	0.02	79.02	51.73	29.19	84.21
7131-Mt(2)	0.04	0.35	0.03	0.00	0.21	0.57	0.03	0.00	0.00	90.54	0.02	0.01	91.78	65.35	31.74	98.32

Oxide Analyses

Sample	SiO ₂	TiO ₂	Nb ₂ O ₅	Al ₂ O ₃	Cr ₂ O ₃	V ₂ O ₅	MgO	CaO	MnO	FeO	NiO	ZnO	Total	Fe ₂ O ₃	FeO	Total
Terrace Bay Batholith																
7171-1ox	0.00	0.00	0.00	0.00	0.23	0.27	0.00		0.00	92.87	0.03	0.02	93.41	68.20	31.50	100.25
7171-2ox	0.04	0.02	0.00	0.00	0.19	0.35	0.00		0.03	92.58	0.06	0.00	93.26	67.78	31.59	100.05
7171-3ox	0.00	0.00	0.00	0.00	0.24	0.32	0.01		0.00	93.03	0.06	0.00	93.66	68.25	31.62	100.50
7171-4ox	0.02	0.00	0.09	0.00	0.14	0.27	0.02		0.05	92.96	0.06	0.00	93.61	68.21	31.58	100.44
7171-5ox	0.01	0.01	0.00	0.00	0.37	0.33	0.01		0.00	92.37	0.07	0.02	93.19	67.67	31.48	99.97
7171-6ox	0.03	0.06	0.13	0.01	0.17	0.31	0.04		0.00	92.76	0.01	0.10	93.62	67.84	31.72	100.42
7171-7ox	0.00	0.01	0.00	0.00	0.19	0.33	0.02		0.01	93.26	0.03	0.02	93.87	68.42	31.70	100.72
7171-8ox	0.03	0.01	0.00	0.00	0.18	0.27	0.03		0.00	93.06	0.07	0.00	93.63	68.34	31.56	100.48
7171-Mt(8)	0.02	0.01	0.03	0.00	0.21	0.31	0.02		0.01	92.86	0.05	0.02	93.53	68.09	31.59	100.35
Picture Island Stock																
7224-1ox * #	3.03	0.00	0.00	0.00	0.01	0.00	0.53		0.00	74.63	0.03	0.03	78.25	50.66	29.04	83.33
7224-2ox	0.04	0.00	0.00	0.00	0.06	0.39	0.04		0.12	92.43	0.00	0.08	93.16	67.80	31.43	99.95
7224-Mt(1)	0.04	0.00	0.00	0.00	0.06	0.39	0.04		0.12	92.43	0.00	0.08	93.16	67.80	31.43	99.95
Pukaskwa Batholith																
7255-1ox	0.04	0.03	0.00	0.00	0.01	0.01	0.00		0.00	92.29	0.05	0.06	92.49	68.33	30.81	99.34
7255-2ox	0.04	0.04	0.00	0.00	0.04	0.02	0.03		0.00	92.02	0.08	0.00	92.27	68.10	30.74	99.09
7255-3ox	0.05	0.03	0.00	0.00	0.03	0.04	0.01		0.00	92.54	0.00	0.07	92.78	68.39	31.00	99.64
7255-4ox	0.05	0.02	0.00	0.00	0.02	0.03	0.06		0.00	91.93	0.04	0.00	92.13	68.05	30.70	98.95
7255-Mt(4)	0.05	0.03	0.00	0.00	0.03	0.03	0.03		0.00	92.20	0.04	0.03	92.42	68.22	30.81	99.26
Black-Pic Batholith																
7146-3ox	0.02	0.40	0.08	0.00	0.05	0.41	0.03		0.00	92.50	0.03	0.04	93.56	67.09	32.13	100.28
7146-6ox	0.04	0.03	0.00	0.00	0.02	0.09	0.01		0.00	92.63	0.02	0.02	92.86	68.37	31.11	99.71
7146-7ox	0.03	0.01	0.05	0.00	0.05	0.19	0.02		0.00	91.92	0.00	0.00	92.26	67.59	31.10	99.03
7146-8ox	0.02	0.02	0.00	0.00	0.04	0.24	0.02		0.00	92.26	0.03	0.00	92.62	67.84	31.22	99.41
7146-9ox	0.05	0.00	0.07	0.00	0.12	0.27	0.02		0.00	93.04	0.02	0.01	93.60	68.19	31.68	100.43
7146-10ox	0.03	0.01	0.00	0.00	0.08	0.26	0.04		0.00	92.67	0.06	0.00	93.13	68.15	31.35	99.96
7146-11ox	0.00	0.02	0.00	0.00	0.05	0.34	0.04		0.00	92.57	0.02	0.02	93.06	67.92	31.46	99.87
7146-mt(7)	0.03	0.07	0.03	0.00	0.06	0.26	0.03		0.00	92.51	0.03	0.01	93.01	67.88	31.44	99.81

Oxide Analyses

Sample	SiO ₂	TiO ₂	Nb ₂ O ₅	Al ₂ O ₃	Cr ₂ O ₃	V ₂ O ₅	MgO	CaO	MnO	FeO	NiO	ZnO	Total Fe ₂ O ₃	FeO	Total
7146-5ox	0.00	8.96	0.07	0.01	0.11	0.53	0.06		0.00	82.38	0.03	0.04	92.19	48.00	97.00
7146-TiMn(1)	0.00	8.96	0.07	0.01	0.11	0.53	0.06		0.00	82.38	0.03	0.04	92.19	48.00	97.00
7146-1ox	0.04	51.15	0.12	0.04	0.00	0.06	0.07		2.72	43.77	0.01	0.40	98.37	0.81	98.45
7146-2ox	0.01	50.81	0.00	0.05	0.00	0.09	0.16		2.54	43.52	0.00	1.09	98.26	1.66	98.43
7146-4ox	0.03	50.75	0.00	0.00	0.01	0.07	0.35		0.79	46.14	0.00	0.41	98.56	2.39	98.80
7146-II(3)	0.03	50.90	0.04	0.03	0.00	0.07	0.19		2.02	44.48	0.00	0.63	98.40	1.62	98.56
7213-1ox	0.00	0.03	0.08	0.00	0.00	0.15	0.04		0.00	92.47	0.03	0.00	92.79	68.14	99.61
7213-2ox	0.03	0.00	0.00	0.00	0.06	0.10	0.03		0.00	92.48	0.01	0.03	92.73	68.31	99.57
7213-3ox	0.03	0.02	0.00	0.00	0.01	0.23	0.00		0.00	92.55	0.00	0.05	92.89	68.06	99.71
7213-4ox	0.01	0.02	0.14	0.00	0.10	0.12	0.02		0.02	92.12	0.00	0.00	92.56	67.77	99.35
7213-5ox	0.02	0.04	0.00	0.00	0.06	0.13	0.01		0.02	92.74	0.02	0.00	93.04	68.37	99.89
7213-6ox	0.05	0.01	0.03	0.01	0.04	0.30	0.01		0.04	92.44	0.00	0.02	92.96	67.78	99.75
7213-7ox	0.01	0.01	0.05	0.00	0.01	0.15	0.07		0.00	92.85	0.01	0.00	93.16	68.47	100.02
7213-8ox	0.06	0.03	0.00	0.00	0.02	0.27	0.02		0.00	92.31	0.02	0.01	92.76	67.73	99.54
7213-9ox	0.03	0.00	0.00	0.00	0.02	0.09	0.03		0.00	92.45	0.03	0.09	92.74	68.36	99.59
7213-10ox	0.02	0.03	0.00	0.00	0.04	0.10	0.02		0.00	92.58	0.03	0.05	92.85	68.40	99.70
7213-11ox	0.02	0.06	0.00	0.00	0.04	0.22	0.00		0.00	92.30	0.06	0.00	92.70	67.85	99.50
7213-12ox	0.00	0.02	0.01	0.00	0.05	0.22	0.01		0.03	93.70	0.01	0.02	94.07	68.97	100.98
7213-13ox	0.04	0.02	0.00	0.00	0.01	0.20	0.05		0.00	92.23	0.03	0.02	92.61	67.91	99.41
7213-14ox	0.04	0.02	0.00	0.00	0.03	0.15	0.01		0.00	92.66	0.01	0.01	92.92	68.27	99.76
7213-M(14)	0.03	0.02	0.02	0.00	0.04	0.17	0.02		0.01	92.56	0.02	0.02	92.91	68.17	99.74

Analytical Conditions

20kV, 15nA, spot size 1-3 microns.

Custom EDS/WDS magnetite routine.

ZAF-4 with off-line correction for Tikh-Vka (LiF) and CrKb-Mnka (PET)

Appendix K. Tabulation of Nd isotopic data for plutons associated with the Hemlo greenstone belt.

	Sample	$^{143}\text{Nd}/^{144}\text{Nd}$	$^{147}\text{Sm}/^{144}\text{Nd}$	Age (Ma)*	$^{143}\text{Nd}/^{144}\text{Nd}^T$	ϵ_{Nd}^T
Black-Pic Batholith	7148	0.510882	0.0907	2720	0.509254	+2.9
	7213	0.510802	0.0861	2720	0.509257	+2.9
Pukaskwa Batholith	7271	0.511050	0.0990	2718	0.509274	+3.2
	7276	0.510874	0.0899	2718	0.509262	+3.0
Dotted Lake Batholith	7079	0.511533	0.1281	2697	0.509253	+2.3
Cedar Lake Pluton	7009	0.511006	0.0994	2688	0.509243	+1.8
	7292	0.511031	0.0972	2688	0.509307	+3.1
	7004B	0.511227	0.1116	2688	0.509248	+1.9
	7009B	0.511129	0.1051	2688	0.509265	+2.3
	7032	0.511046	0.0996	2688	0.509280	+2.6
Heron Bay Pluton	7072	0.511072	0.1030	2690	0.509244	+1.9
	7094	0.511086	0.1037	2690	0.509246	+1.9
	7118	0.511171	0.1069	2690	0.509274	+2.5
	7153	0.511157	0.1054	2690	0.509286	+2.7
Gowan Lake Pluton	7175	0.511251	0.1132	2677	0.509252	+1.7
	7250	0.510998	0.0984	2677	0.509260	+1.9
	7236B	0.511114	0.1046	2677	0.509267	+2.0
Fourbay Lake Pluton	7241	0.511052	0.1001	2678	0.509283	+2.4
Cedar Creek Stock	7296	0.511074	0.1022	2684	0.509264	+2.1
Botham Stock Grdr	7066	0.511111	0.1039	2689	0.509268	+2.3
	7066dup	0.511127	0.1059	2689	0.509248	+2.0
Musher Lake Pluton	7207	0.511072	0.1015	2679	0.509278	+2.3
Melgund Stock	7131	0.511302	0.1148	2686*	0.509268	+2.3
Picture Island Pluton	7224	0.510785	0.0856	2686*	0.509268	+2.3
Moose Lake Porphyry	7109	0.511045	0.0988	2693	0.509289	+2.9
Feldspar Porphyry Dike	7065	0.511220	0.1100	2687	0.509270	+2.3
White River Pluton	7041	0.511227	0.1108	2691*	0.509260	+2.2
	7043	0.511208	0.1090	2691*	0.509273	+2.5
Terrace Bay Batholith	7171	0.511079	0.1020	2686*	0.509271	+2.3

* Ages marked with an asterisk are estimated from field relationships for the purpose of calculating ϵ_{Nd}

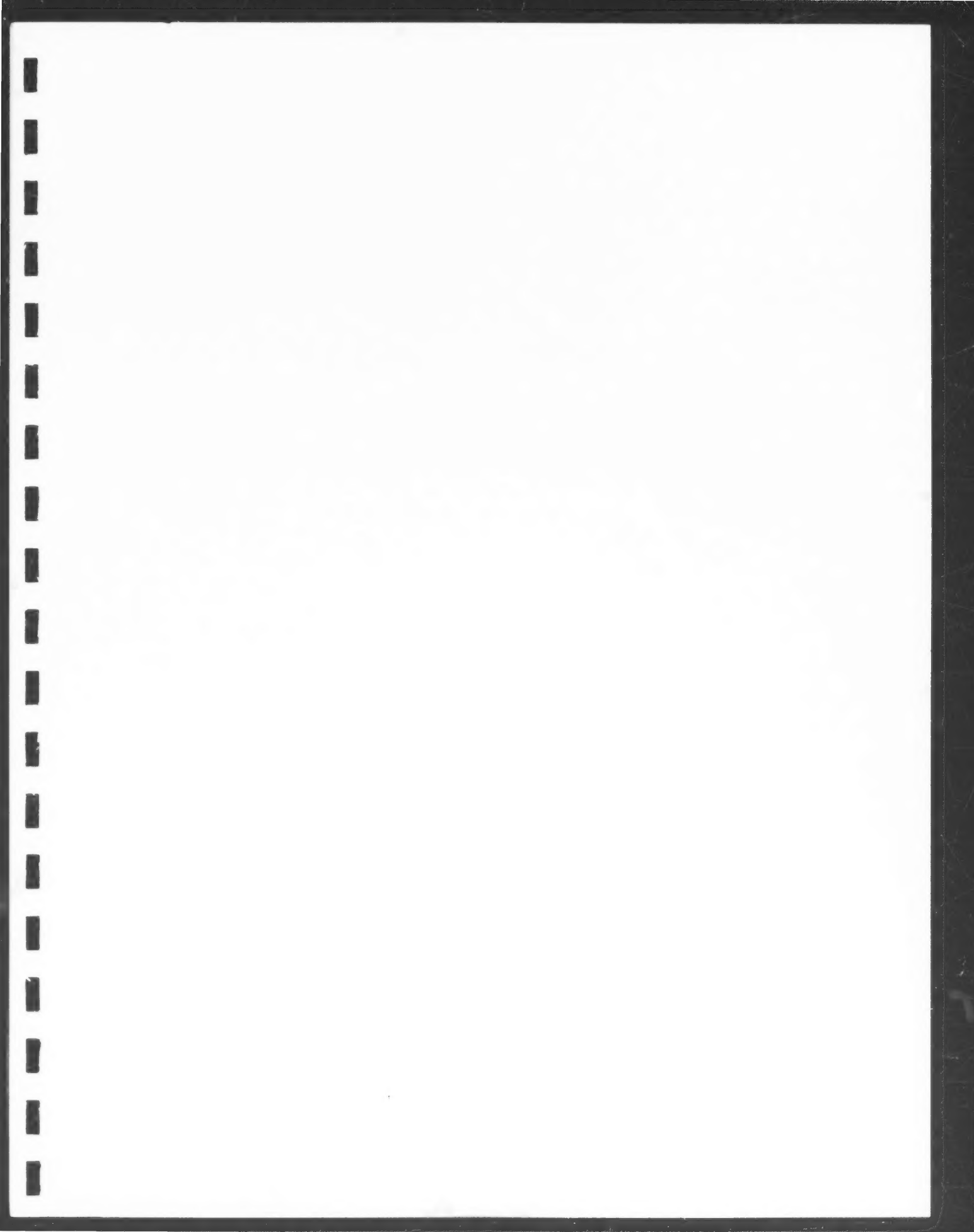
Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	Multiplied by	Gives	Imperial Unit	Multiplied by	Gives
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 023	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 90	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.



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